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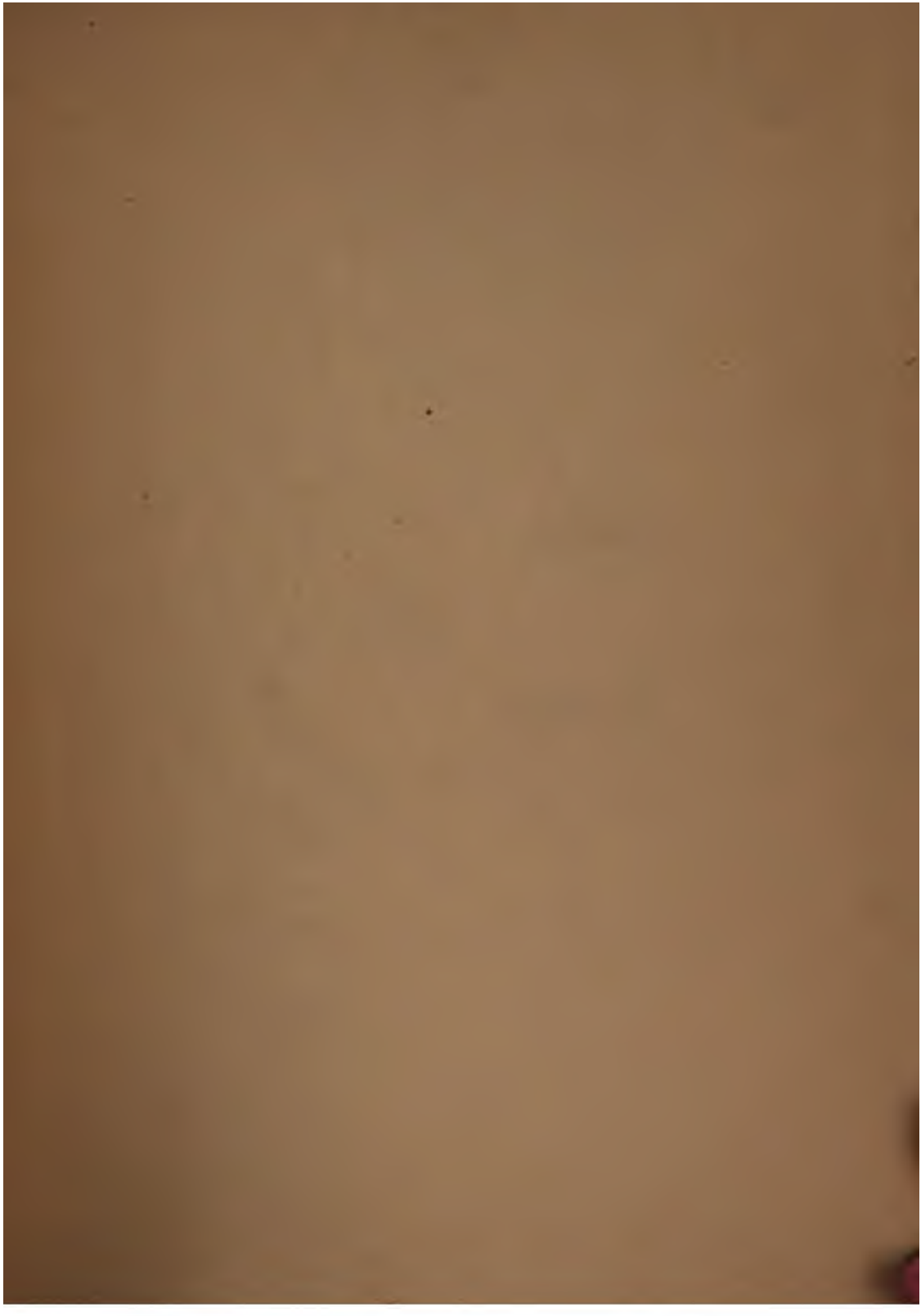

SUMMARY

OF THE

COURSE OF PERMANENT FORTIFICATION

AND OF THE

ATTACK AND DEFENCE OF PERMANENT WORKS

FOR THE USE OF THE

CADETS OF THE U.S. MILITARY ACADEMY

By D. H. MAHAN, PROFESSOR OF MILITARY ENGINEERING. &c. &c.

* * *

WEST POINT, N.Y.

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1850

Summary of the Course of Permanent Fortification

System of Fortification Drawing.

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2. To obviate these difficulties, engineers have adopted the method of assuming, at an arbitrary distance, either above, or below some fixed point of the works, or of the site, a horizontal plane, upon which the horizontal projections of all the

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2. To obviate these difficulties, engineers have adopted the method of assuming, at an arbitrary distance, either above, or below some fixed point of the works, or of the site, a horizontal plane, upon which the horizontal projections of all the

parts are represented, and of designating the vertical distances of all points from this plane by means of numbers, expressed in terms of some linear unit, as a foot, or yard, which are written near the projections of the points.

This method, as will be apparent from subsequent applications, is more simple, requires less labor, and enables the eye to seize with more distinctness the forms and relative positions of all the parts than in the usual methods of descriptive geometry.

The plane on which the horizontal projections are made is termed the plane of reference, or plane of comparison; the numbers which designate the vertical distances of the points projected from this plane are termed the references of the points, or simply references.

As has been stated, the plane of reference may be taken either above, or beneath every point of the object to be represented. It is most usual to take it beneath the object, as the mind is more accustomed to consider the vertical dimensions of objects rather with respect to some fixed point, or plane, below them than from above downwards; and such will be the position assumed for it in the subsequent applications.

The reference of any point, or line of the plane of reference will therefore be zero; that of any point above it will be expressed in feet; decimal parts of a foot being used when-

ever the reference is not an entire number. In writing the reference the mark used to designate the linear unit is omitted.

3. To designate the position of a point, (Fig 1) the projection of the point and its reference are enclosed within a bracket, thus (. 28,50.) This expresses that the vertical distance of the point from the plane of reference is 28 feet and 50 hundredths of a foot.

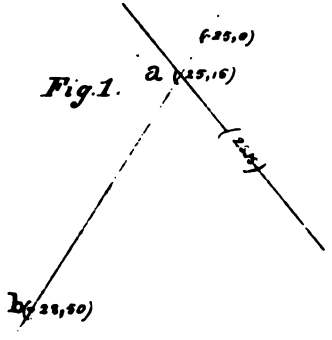

Fig. 1.

The position of a right line oblique to the plane of reference is designated by the projection of the line, and the references of any two of its points. Thus in (Fig 1.) the points a, and b, upon the projection of the right line, with their respective references (25,15) and (28,50) determine the position of the line with respect to the plane of reference.

When the line is horizontal, or parallel to the plane of reference, its projection, with the reference of one of its points, will be sufficient to designate it, and fix its position with respect to the plane of reference. Thus in (Fig 1.) the reference (25,15), written upon the projection of the line, expresses that the line is horizontal, and 25,15 feet from the plane of reference.

4. For the convenience of numerical calculation, the position of a line, with respect to the plane of reference,

is often expressed in terms of the natural tangent of the angle it makes with the plane; but as this angle is the same as that between the line and its projection, its natural tangent can be expressed by the difference of level between any two points of the line divided by the horizontal distance between the points. Now, as the difference of level between any two points of the line is the same as the difference of the references of the points, and the horizontal distance between them is the same as the horizontal projection of the portion of the line between the same points, it follows, that the natural tangent of the angle which the line makes with the plane of reference is found by dividing the difference of the references of the points by the distance in horizontal projection between them.

The fraction which expresses this tangent is termed the inclination, or declivity of the line. Thus the fraction $\frac{1}{6}$ would express that the horizontal distance between any two points is six times the vertical distance, or difference of their references; the fraction $\frac{2}{3}$, that the vertical distance between any two points is two-thirds the horizontal distance; the denominator of the fraction, in all cases, representing the number of parts in horizontal projection, and the numerator the corresponding number of parts in vertical distance.

When the position of a line is designated in this way, it is said to be a line whose inclination, or declivity is

one sixth, two-thirds, ten on one, &c; or simply, a line of one sixth, &c

5. When the projection of a line is divided into equal parts, each of which corresponds to a unit in vertical distance, and the reference of the points of division are written, it is termed the scale of declivity of the line. In constructing the scale of declivity of a line, the entire references are alone put down; one of the divisions of the equal parts being subdivided into tenths, or hundredths if necessary, so as to give the fractional parts of the references corresponding to any fractional part of an entire division.

6. Having the inclination of a line, the difference of reference of any two of its points, the projections of which are given, will be found by multiplying the horizontal distance between them by the fraction which expresses this inclination; in like manner the horizontal distance of any two points will be obtained by dividing the difference of their references by this fraction.

To obtain therefore the reference of a point of a line, having its projection, the horizontal distance between it and that of some other known point of the line must be determined, from the scale of the drawing by which the horizontal distances are measured; this distance expressed in numbers, being multiplied by the fraction which expresses the inclination of the line will give the difference of

the two points; the required reference of the point will be found by subtracting this product from the reference of the known point; if it is higher than the one sought, or adding if it is lower. Thus let 25,15 be the reference of a known point higher than the one sought; the distance between the points being 35,57 feet, and the inclination of the line $\frac{1}{10}$; then $35.75 \times \frac{1}{10} = 3,575$ will be the difference of reference of the points, and $25,15 - 3,575 = 21,575$ the required reference. The converse of this shows that the horizontal distance between two points on this line whose difference of reference is 3,575 will be $3,575 \div \frac{1}{10} = 35,75$ feet.

The true length of any portion of a line between two given points is evidently the hypothenuse of a right angle triangle of which the other two sides are the difference of reference of the points, and their horizontal distance.

7. The position of a plane oblique to the plane of reference may be determined either by the projections and references of three of its points; by the projections and declivity of two lines in it oblique to the plane of reference; or by the projection of two, or more horizontal lines of the plane, with their references.

The more usual method of representing a plane is by the projections on the plane of reference of the horizontal lines determined by intersecting it by equidistant horizontal planes. These lines are termed the horizontals

of the plane, and those are usually taken the references of which are entire numbers.

8. If in a plane given by its horizontals, a line be drawn perpendicular to the horizontals, its projection on the plane of reference will be also perpendicular to the projections of the horizontals. The angle of this line with the plane of reference is evidently the same as that of the given plane with it, and is greater than the angle between any other line drawn in the plane and the plane of reference. This line is, on this account, termed the line of greatest declivity of the plane.

9. If the scale of declivity of the line of greatest declivity is constructed it will alone serve to fix the position of the plane to which it belongs, and to determine the reference of any point of the plane of which the projection is given. For the inclination of this line and that of the plane are the same; and as the horizontals are perpendicular to the line of greatest declivity the point where the horizontal drawn through the given projection of a point cuts this line will determine upon the scale the reference of the horizontal, and therefore that of the point.

10 The inclination, or declivity of a plane with the plane of reference may be expressed in the same way as the inclination of its line of greatest declivity. Thus a plane of one fourth; a plane of twenty on one; a plane of

two-thirds, express that the natural tangent of the angle between the planes and the plane of reference are respectively represented by the fractions $\frac{1}{2}$, $\frac{2}{3}$ and $\frac{4}{5}$.

11. The horizontal distance between two horizontals of a plane, the angle of which is given, can be found in the same way as the horizontal distance between two points of a line the inclination of which is given (Art. 6) by dividing the difference of reference of the horizontals by the fraction representing the inclination of the plane; in like manner the difference of reference of two horizontals will be obtained by multiplying their horizontal distance by the same fraction.

12. To distinguish the scale of declivity (Fig. 2) from any other line of a plane, it is always represented by two fine parallel lines, drawn near each other, and crossed at the points of division, where the references are written, by short lines which are portions of the corresponding horizontals.

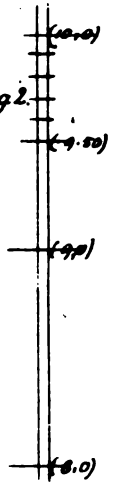

Fig 2.

With the foregoing elements the usual problems of the right line and plane can be readily solved.

13. *Prob. 1. Fig. 3.* Having the projections and references of two lines that intersect to find the angle between them

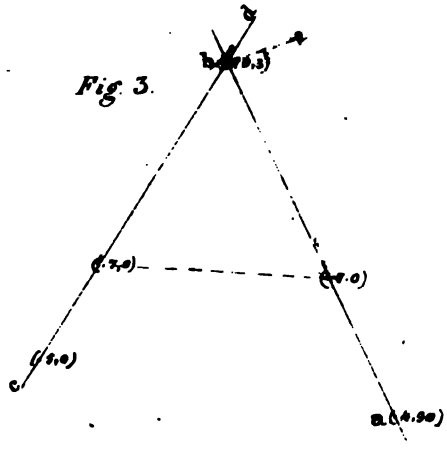

Fig. 3.

Let a b be the projection of one of the lines, the references of two of its points (10,30), and (4,30), being given; c d the projection of the other line, (10,30), and (5,0) being the references of two of its points; (10,30) being the point of intersection of the two lines

Find on each of the lines (Art. 6) a point having the same reference (7,0). The line joining these two points will be horizontal, and projected into its true length; taking this line as the base of the triangle of which the other two sides are respectively the true lengths of the portions of the two given lines projected between (10,30), and (7,0) (Art 6), the angle at the vertex will be the one required.

14. *Prob. 2. Fig. 4.* Through a point to draw a line parallel to a given line.

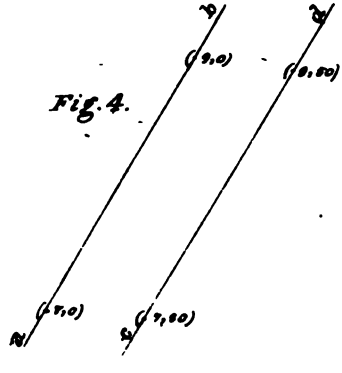

Fig. 4.

Let c (7,50), be the projection of the point; a b that of the given line of which the two points (7,0), and (9,0) are known.

Through c drawing c d parallel to a b, this will be the projection of the required line; as its

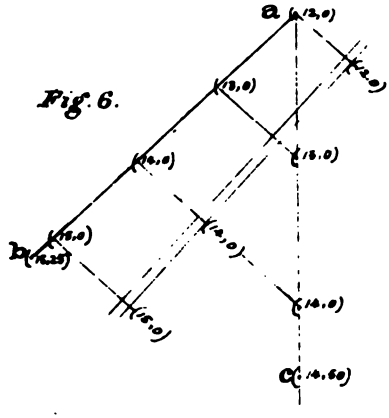

Fig. 6.

lines of junction (Art. 4.). The lines joining the same references on these two lines will be horizontals of the required plane. The scale of its declivity will be found by drawing a line perpendicular to the horizontals, and writing the references of the points where it intersects them.

17. *Prob. 5. Fig. 7.* To find the horizontals of a plane passed through a given line and parallel to another line.

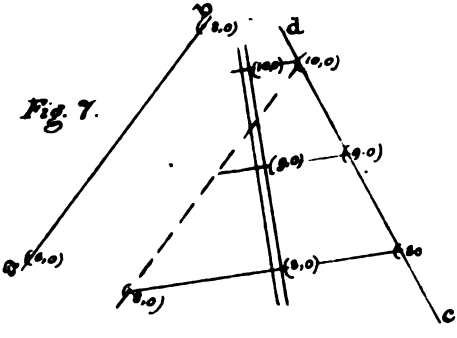

Fig. 7.

Let ab, and cd, be the projections of the two lines. From a point (10,0), on cd draw a line (Prob. 2) parallel to ab; and by (Prob. 4) find the horizontals of the plane of this line and cd; these will be required horizontals.

18. *Prob. 6. Fig. 8.* To find the horizontals of a plane the declivity of which is given, and which passes through a given line.

Let bd be the scale of declivity of the given line.

Since the horizontals of the plane must pass through the points of the line having the like references, and as the

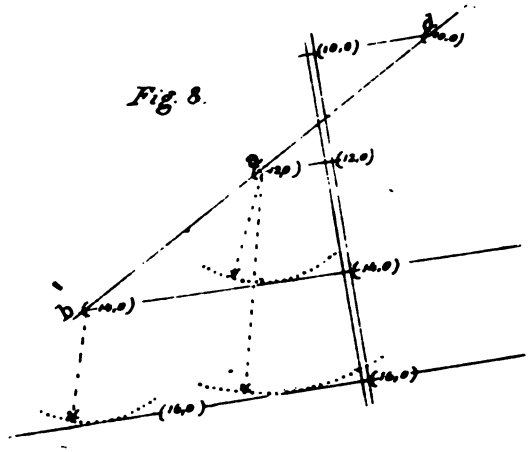

Fig. 8.

distance in projection between any two of them (Art. 11) will be equal to the difference of their references divided by the fraction of inclination of the plane, it follows that to find the one drawn through b(14,0), for example, it will be simply necessary to describe from any other point, as a (12,0); or d(10,0), an arc of a circle, with a radius equal to the quotient just mentioned, and to draw a tangent to this arc from b.

If any other horizontal, as (10,0), is required, which would not intersect the given line within the limits of the drawing; any two points, as (12,0), and (14,0) for example, may be taken as centres, and two arcs be described from them, with radii calculated as above; a line drawn tangent to the arcs, will be the required horizontal.

19. Prob. 7. Fig. 9. Having the horizontals, or the scales of declivity of two planes to find their intersection.

Join the points where any two horizontals as (12,0) and (14,0), in one plane intersect two corresponding horizontals of the other, and the line so found will be the projection of the required intersection.

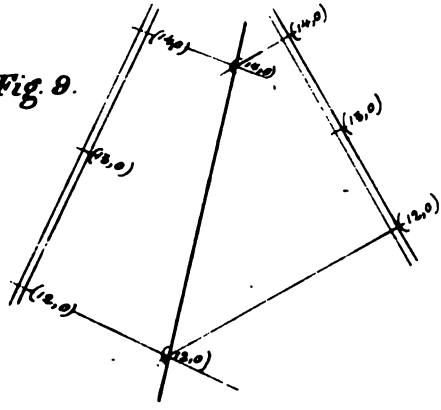

Fig. 9.

When the horizontals are parallel, or when they are so nearly parallel that their points of intersection cannot be readily found, the following method may be taken. Draw any two parallel lines as c d, c′ d′, (Fig. 10); these may be considered as the horizontals of an arbitrary plane having the same references (12,0), and (14,0), as two corresponding horizontals in each of the given planes. The intersections of the horizontals of the arbitrary plane with those of the given planes will determine two lines which, being the intersections of the given planes with the arbitrary plane, will, by their intersection o, determine a point common to the three planes, and therefore a point of the intersection of the two given planes. Assuming any other two parallels a b, a′ b′, as the horizontals of another arbitrary plane; finding the point o′ common to

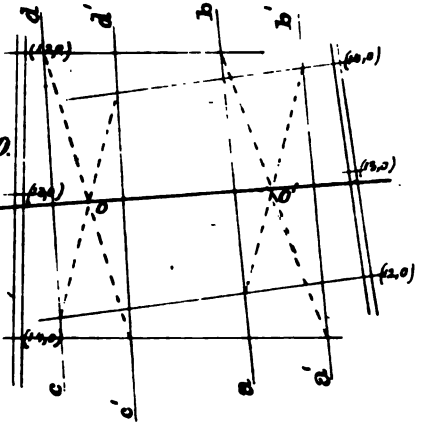

Fig. 10.

the three planes: and joining o and o' by a line, this will be the required intersection.

When the horizontals of the two planes are parallel one point, as o, will be sufficient to determine the intersection, as its projection will be parallel to the horizontals.

20. *Prob 8. Fig. 11.* To find where a given line pierces a given plane.

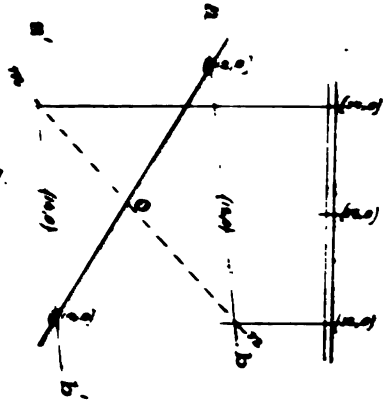

Fig. 11.

Through any two points of the line, having the same references as two horizontals of the given plane, draw two parallel lines ab, a'b', which may be taken as the horizontals of an arbitrary plane. The line of intersection m n of this plane with the given plane being determined, by [Prob 7], the point o where it intersects the given line will be the projection of the required point.

21 *Prob 9. Fig. 12.* To draw from a given point a perpendicular to a given plane, and find its length.

Let a a' be the given point; and the given plane be represented by its scale of declivity.

The projection of the required perpendicular will pass through a, and be parallel to the scale of declivity of the given plane. The angle which it makes with the plane of reference

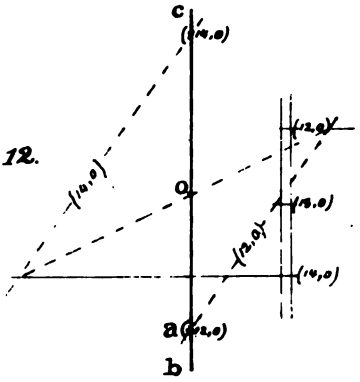

Fig. 12.

is the complement of that between this plane and the given plane; its tangent therefore will be the reciprocal of the tangent of that of the given plane.

Drawing therefore through a, the line bc parallel to the scale of declivity of the plane, and constructing its scale of declivity (Art. 6.), this will be the projection of the required perpendicular. The point o where it pierces the given plane is found by (Prob. 8); and its true length by (Art. 6.).

22. Prob. 10. Fig. 13. To find the angle between a line and plane.

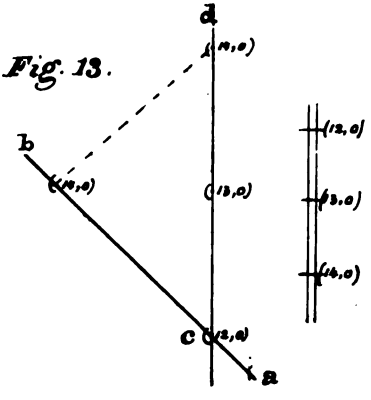

Fig. 13.

Let ab be the projection of the given line; the plane being given by its scale of declivity.

Through any point c(12,0), of the line draw a perpendicular cd to the given plane, by (Prob. 9.), and construct its scale of declivity. Find by (Prob. 1) the angle at c, between the given line and this perpendicular; this will be the complement of the angle between the plane and line.

the two points; the required reference of the point will be foun by subtracting this product from the reference of the known point; if it is higher than the one sought; or adding if it is lower. Thus let 25,15 be the reference of a known point highe than the one sought; the distance between the points being 35,57 feet, and the inclination of the line $\frac{1}{10}$; then $35.75 \times \frac{1}{10} = 3,575$ will be the difference of reference of the points, and $25,15 - 3,575 = 21,575$ the required reference. The converse of this shows that the horizontal distance between two points on this line whose difference of reference is 3,575 will be $3,575 \div \frac{1}{10} = 35,75$ feet.

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11 The horizontal distance between two horizontals of a plane, the angle of which is given, can be found in the same way as the horizontal distance between two points of a line the inclination of which is given (Art 6) by dividing the difference of reference of the horizontals by the fraction representing the inclination of the plane; in like manner the difference of reference of two horizontals will be obtained by multiplying their horizontal distance by the same fraction.

12 To distinguish the scale of declivity (Fig. 2) from any other line of a plane, it is always represented by two fine parallel lines, drawn near each other, and crossed at the points of division, where the references are written, by short lines which are portions of the corresponding horizontals.

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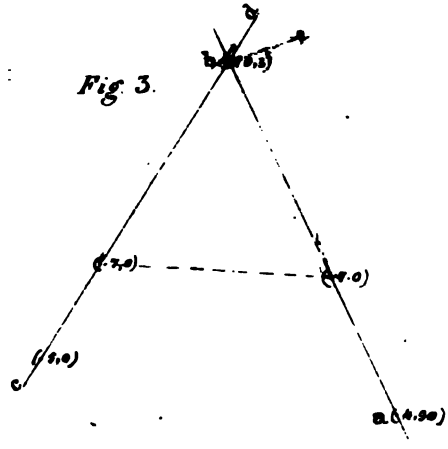


Fig. 3.

Let a b be the projection of one of the lines, the references of two of its points (10,30), and (4,90), being given; c d the projection of the other line, (10,30), and (5,0) being the references of two of its points; (10,30) being the point of intersection of the two lines.

Find on each of the lines (Art. 6) a point having the same reference (7,0). The line joining these two points will be horizontal, and projected into its true length; taking this line as the base of the triangle of which the other two sides are respectively the true lengths of the portions of the two given lines projected between (10,30), and (7,0) (Art 6), the angle at the vertex will be the one required.

14. Prob. 2. Fig. 4. Through a point to draw a line parallel to a given line.

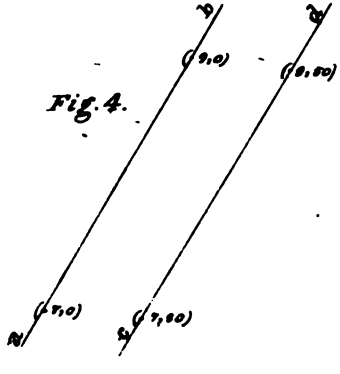


Fig. 4.

Let c (7,50), be the projection of the point; a b that of the given line of which the two points (7,0), and (0,0) are known.

Through c drawing c d parallel to a b, this will be the projection of the required line; as its

ivity is the same as that of the given line, it will be only ne-
ry to set off from c towards d, the same distance as between
1 and (0,0), to obtain a point (0,50), as far above (7,50), as (0,0
bove (7,0).

Prob.3. Fig.5. Through a point in a plane to draw a line
he plane with a given inclination.

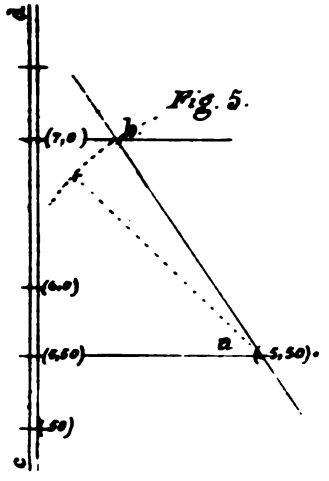


Fig. 5.

Let c d be the scale of declivity of the given plane, and a (5,50) the given point.

Draw the horizontal of the plane (5,50) which passes through the point, and any other horizontal as (7,0). The projection of the required line will pass through a, and the portion of it between the two horizontals will be equal (Art.16) the difference of their references divided by the fraction which represents the inclination of the required line. Describing therefore, a, an arc, with this distance as a radius, and joining the point here it cuts the horizontal (7,0), with a, this will be the pro-
ion of the required line.

Prob.4. Fig.6. Having three points of a plane to con-
ct its horizontals and scale of declivity.

Let a (12,0), b, (15,25), and c (14,50) be the three points. Join lowest a with the other two, and find the inclination of the

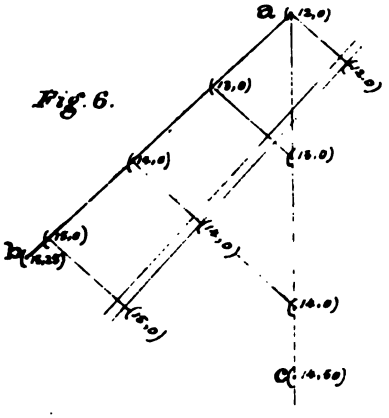


Fig. 6.

lines of junction (Art. 4.). The lines joining the same references on these two lines will be horizontals of the required plane. The scale of its declivity will be found by drawing a line perpendicular to the horizontals, and writing the references of the points where it intersects them.

17. *Prob. 5. Fig. 7.* To find the horizontals of a plane passed through a given line and parallel to another line.

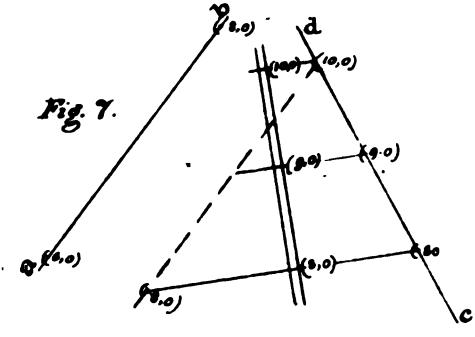


Fig. 7.

Let ab, and cd, be the projections of the two lines. From a point (10,0), on cd draw a line (Prob. 2) parallel to ab; and by (Prob. 4) find the horizontals of the plane of this line and cd; these will be required horizontals.

18. *Prob. 6. Fig. 8.* To find the horizontals of a plane the declivity of which is given, and which passes through a given line.

Let bd be the scale of declivity of the given line.

Since the horizontals of the plane must pass through the points of the line having the like references, and as the

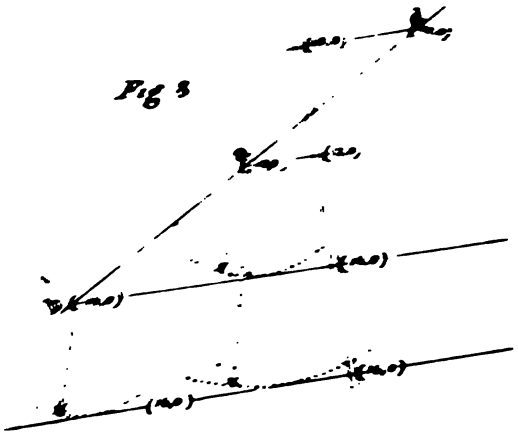


Fig 3

distance on projection between any two of them (Art 11) will be equal to the difference of their references divided by the fraction of inclination of the plane, it follows that to find the one drawn through b (10.0), for example, it will be simply necessary to describe from any other point, as a (12,0); or d (10.0), an arc of a circle, with a radius equal to the quotient just mentioned, and to draw a tangent to this arc from b.

If any other horizontal, as (10,0), is required, which would not intersect the given line within the limits of the drawing; any two points, as (12,0), and (14,0) for example, may be taken as centres, and two arcs be described from them, with radii calculated as above; a line drawn tangent to the arcs, will be the required horizontal

19. Prob. 7. Fig. 9. Having the horizontals, or the scales of declivity of two planes to find their intersection.

Join the points where any two horizontals as (12,0) and (14,0), in one plane intersect two corresponding horizontals of the other, and the line so found will be the projection of the required intersection.

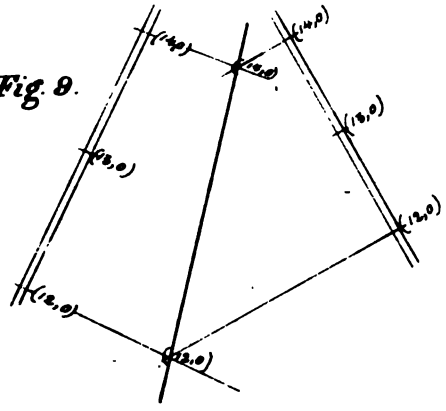


Fig. 9.

When the horizontals are parallel, or when they are so nearly parallel that their points of intersection cannot be readily found, the following method may be taken. Draw any two parallel lines as c d, c' d', (Fig. 10); these may be considered as the horizontals of an arbitrary plane having the same references (12,0), and (14,0), as two corresponding horizontals in each of the given planes. The intersections of the horizontals of the arbitrary plane with those of the given planes will determine two lines which, being the intersections of the given planes with the arbitrary plane, will, by their intersection o, determine a point common to the three planes, and therefore a point of the intersection of the two given planes. Assuming any other two parallels a b, a' b', as the horizontals of another arbitrary plane; finding the point o' common to

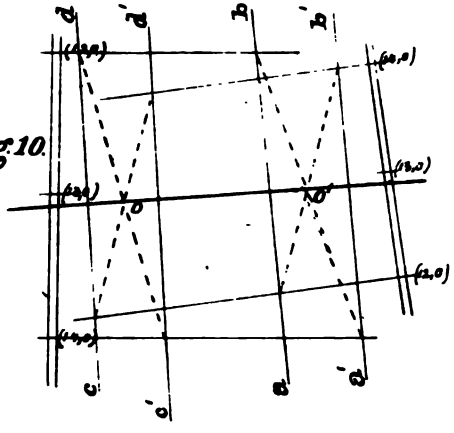


Fig. 10.

the three planes; and joining o and o' by a line, this will be the required intersection.

When the horizontals of the two planes are parallel one point, as o, will be sufficient to determine the intersection, as its projection will be parallel to the horizontals.

20. *Prob. 8. Fig. 11.* To find where a given line pierces a given plane.

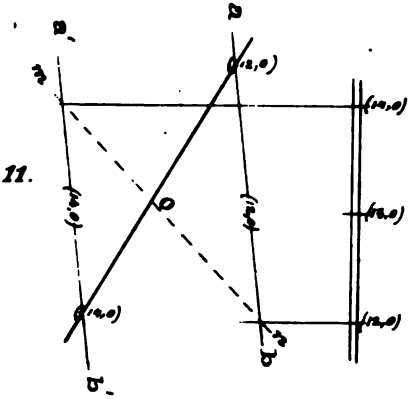


Fig. 11.

Through any two points of the line, having the same references as two horizontals of the given plane, draw two parallel lines ab, a'b', which may be taken as the horizontals of an arbitrary plane. The line of intersection m n of this plane with the given plane being determined, by [Prob. 7], the point o where it intersects the given line will be the projection of the required point.

21. *Prob. 9. Fig. 12.* To draw from a given point a perpendicular to a given plane, and find its length.

Let a (12,0) be the given point; and the given plane be represented by its scale of declivity.

The projection of the required perpendicular will pass through a, and be parallel to the scale of declivity of the given plane. The angle which it makes with the plane of reference

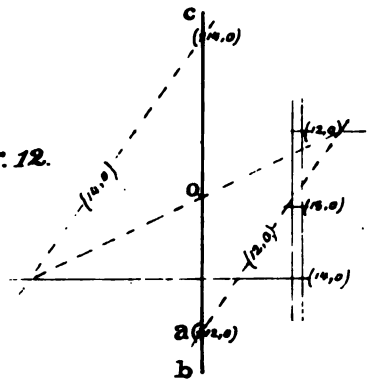


Fig. 12.

is the complement of that between this plane and the given plane; its tangent therefore will be the reciprocal of the tangent of that of the given plane.

Drawing therefore through a, the line bc parallel to the scale of declivity of the plane, and constructing its scale of declivity (Art. 6.), this will be the projection of the required perpendicular. The point o where it pierces the given plane is found by (Prob. 8); and its true length by (Art. 6.).

22. *Prob. 10. Fig. 13.* To find the angle between a line and plane.

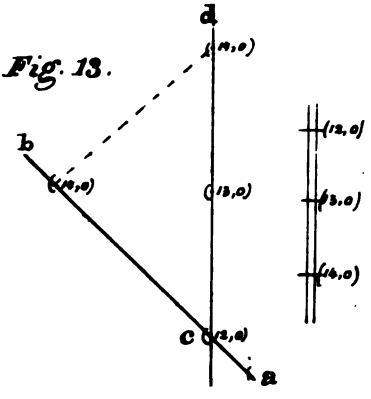


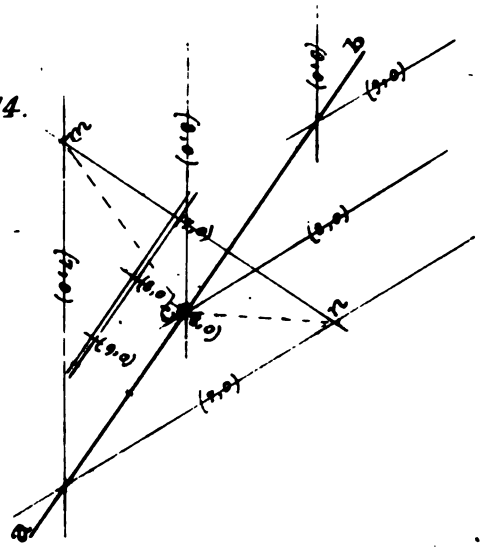
Fig. 13.

Let ab be the projection of the given line; the plane being given by its scale of declivity.

Through any point c(12,0), of the line draw a perpendicular cd to the given plane, by (Prob. 9.), and construct its scale of declivity. Find by (Prob. 1) the angle at c, between the given line and this perpendicular; this will be the complement of the angle between the plane and line.

23. *Prob. 11. Fig. 14.* To find the angle between two given planes.

Fig. 14.



Let (8,0), and (9,0) be two horizontals in each of the planes, and a b their line of intersection.

Through any point c (8,0), of a b, pass a plane perpendicular to it, and construct (Prob. 8) its scale of declivity. Find the points m, and n, where horizontal (7,0) of this plane, (Prob. 7), pierces the two given planes. The line m n will be the base of a triangle, the angle at the vertex of which will be formed by the true lengths of the lines between m c, and n c, and will be the required angle.

24. All other surfaces may like the plane, (Art. 7.), be represented by the projections on the plane of reference of the curves cut from them by equidistant horizontal planes, together with the references of these curves; as many of these curves being drawn as may be requisite to determine all the points of the surface with accuracy.

In the more simple geometrical surfaces, a single horizontal curve with the projection of some point, or line of the surface will alone suffice. For example, the cone may be represented by the projection and reference of any curve cut from it by a horizontal plane, with the projection and reference of its vertex; a cylinder by the projection and reference of a like curve, with the projection and reference of one of its right line elements; a sphere by the projection and reference of its centre and that of its great circle parallel to the plane of reference.

25. The application of this method of projection to the solution of the usual problems of tangent and secant planes to geometrical surfaces is of extreme simplicity. A single example will be sufficient to show this and to serve as an illustration of other cases.

26. *Prob. 12. Fig. 15.* Through a line to pass a plane tangent to a sphere.

Let ab be the projection of the given line, (20,0) the reference of the centre of the sphere and that of its horizontal great circle, the projections of these being given.

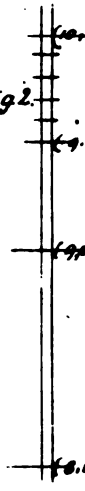
Draw from the point c (20,0) of the given line two tangents to the projection of the great circle. The line fg, drawn through the points of contact, will be the projection of the plane of the circle of contact of the cone, whose vertex is c, with the sphere; and the point i (22,0), where fg prolonged intersects ab, will be the projection of the point

two-thirds, express that the natural tangent of the angle between the planes and the plane of reference are respectively represented by the fractions $\frac{1}{2}$, $\frac{2}{1}$ and $\frac{2}{3}$.

11. The horizontal distance between two horizontals of a plane, the angle of which is given, can be found in the same way as the horizontal distance between two points of a line the inclination of which is given (Art. 6) by dividing the difference of reference of the horizontals by the fraction representing the inclination of the plane; in like manner the difference of reference of two horizontals will be obtained by multiplying their horizontal distance by the same fraction.

12. To distinguish the scale of declivity (Fig. 2) from any other line of a plane, it is always represented by two fine parallel lines, drawn near each other, and crossed at the points of division, where the references are written, by short lines which are portions of the corresponding horizontals.

Fig 2.



With the foregoing elements the usual problems of the right line and plane can be readily solved.

13. Prob. 1. Fig. 3. Having the projections and references of two lines that intersect to find the angle between them.

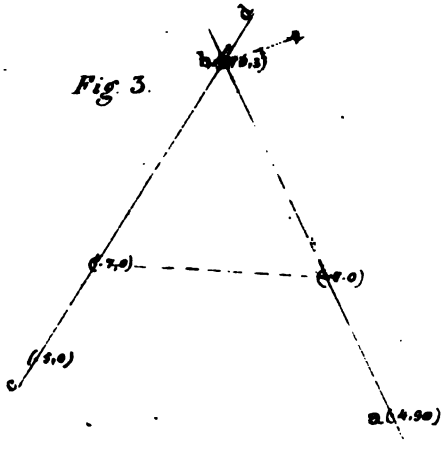


Fig. 3.

Let a b be the projection of one of the lines, the references of two of its points (10,30), and (4,30), being given; c d the projection of the other line, (10,30), and (5,0) being the references of two of its points; (10,30) being the point of intersection of the two lines.

Find on each of the lines (Art. 6) a point having the same reference (7,0). The line joining these two points will be horizontal, and projected into its true length; taking this line as the base of the triangle of which the other two sides are respectively the true lengths of the portions of the two given lines projected between (10,30), and (7,0) (Art 6), the angle at the vertex will be the one required.

14. Prob. 2. Fig. 4. Through a point to draw a line parallel to a given line.

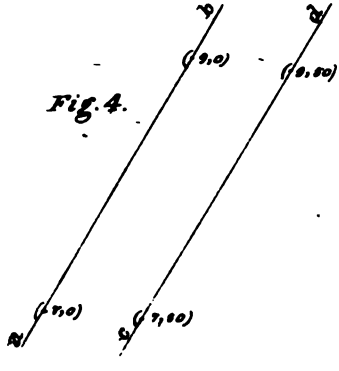


Fig. 4.

Let c (7,50), be the projection of the point; a b that of the given line of which the two points (7,0), and (9,0) are known.

Through c drawing c d parallel to a b, this will be the projection of the required line; as its

declivity is the same as that of the given line, it will be only necessary to set off from c towards d, the same distance as between (7,0) and (9,0), to obtain a point (9,50), as far above (7,50), as (9,0) is above (7,0).

15. *Prob. 3. Fig. 5.* Through a point in a plane to draw a line in the plane with a given inclination.

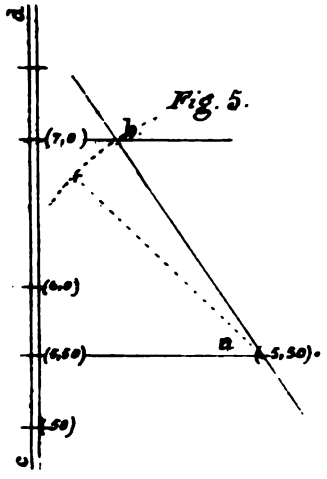


Fig. 5.

Let c d be the scale of declivity of the given plane, and a (5,50) the given point.

Draw the horizontal of the plane (5,50) which passes through the point; and any other horizontal as (7,0). The projection of the required line will pass through a, and the portion of it between the two horizontals will be equal (Art. 16) to the difference of their references divided by the fraction which represents the inclination of the required line. Describing therefore, from a, an arc, with this distance as a radius, and joining the point b, where it cuts the horizontal (7,0), with a, this will be the projection of the required line.

16. *Prob. 4. Fig. 6.* Having three points of a plane to construct its horizontals and scale of declivity.

Let a (12,0), b (15,25), and c (14,50) be the three points. Join the lowest a with the other two, and find the inclination of the

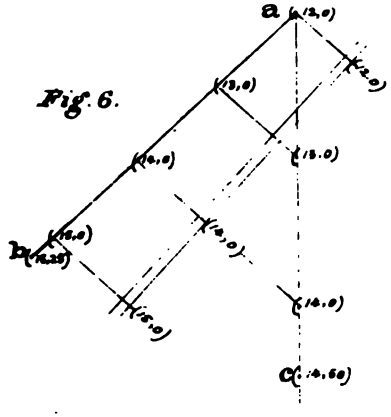


Fig. 6.

lines of junction (Art. 4.). The lines joining the same references on these two lines will be horizontals of the required plane. The scale of its declivity will be found by drawing a line perpendicular to the horizontals, and writing the references of the point where it intersects them.

17. *Prob. 5. Fig. 7.* To find the horizontals of a plane passed through a given line and parallel to another line.

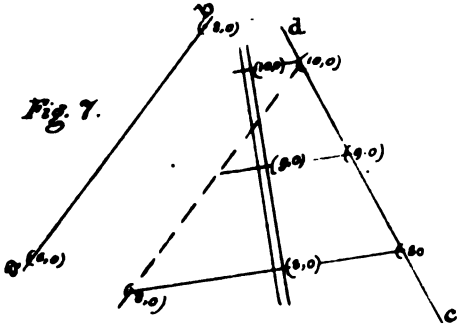


Fig. 7.

Let ab, and cd, be the projections of the two lines. From a point (10,0), on cd draw a line (Prob. 2) parallel to ab; and by (Prob. 4) find the horizontals of the plane of this line and cd; these will be required horizontals.

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Since the horizontals of the plane must pass through the points of the line having the like references, and as the

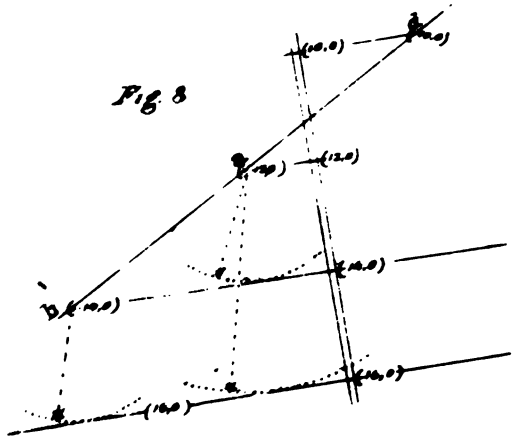


Fig. 8

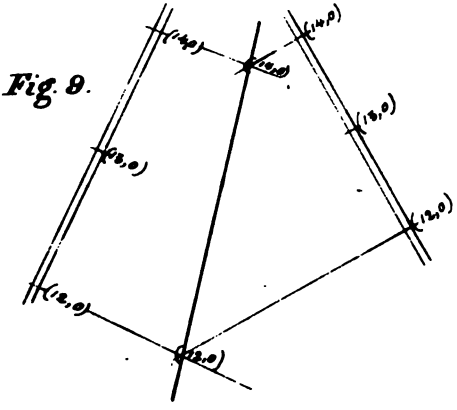
distance in projection between any two of them (Art. 11) will be equal to the difference of their references divided by the fraction of inclination of the plane, it follows that to find the one drawn through b (10,0), for example, it will be simply necessary to describe from any other point, as a (12,0); or d (10,0), an arc of a circle, with a radius equal to the quotient just mentioned, and to draw a tangent to this arc from b.

If any other horizontal, as (10,0), is required, which would not intersect the given line within the limits of the drawing; any two points, as (12,0), and (14,0) for example, may be taken as centres, and two arcs be described from them, with radii calculated as above; a line drawn tangent to the arcs, will be the required horizontal.

19. *Prob. 7. Fig. 9.* Having the horizontals, or the scales of declivity of two planes to find their intersection.

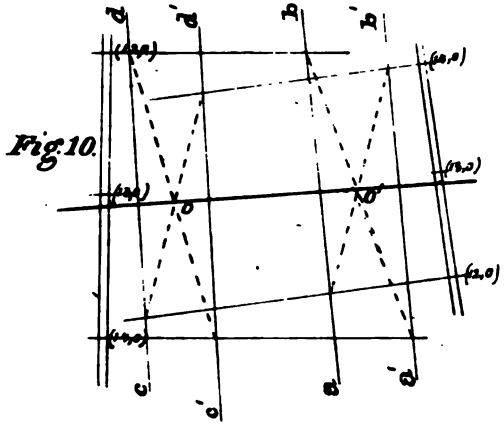
Join the points where any two horizontals as (12,0) and (14,0), in one plane intersect two corresponding horizontals of the other, and the line so found will be the projection of the required intersection.

Fig. 9.



When the horizontals are parallel, or when they are so nearly parallel that their points of intersection cannot be readily found, the following method may be taken. Draw any two parallel lines as c d, c' d', (Fig. 10); these may be considered as the horizontals of an arbitrary plane having the same references (12,0), and (14,0), as two corresponding horizontals in each of the given planes. The intersections of the horizontals of the arbitrary plane with those of the given planes will determine two lines which, being the intersections of the given planes with the arbitrary plane, will, by their intersection o, determine a point common to the three planes, and therefore a point of the intersection of the two given planes. Assuming any other two parallels a b, a' b', as the horizontals of another arbitrary plane; finding the point o' common to

Fig. 10.



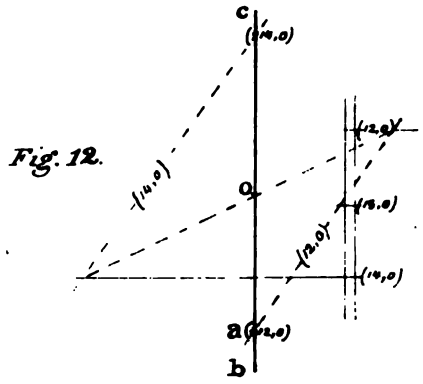


Fig. 12.

is the complement of that between this plane and the given plane; its tangent therefore will be the reciprocal of the tangent of that of the given plane.

Drawing therefore through a, the line bc parallel to the scale of declivity of the plane, and constructing its scale of declivity (Art. 6.), this will be the projection of the required perpendicular. The point o where it pierces the given plane is found by (Prob. 8); and its true length by (Art. 6.).

22. *Prob. 10. Fig. 13.* To find the angle between a line and plane.

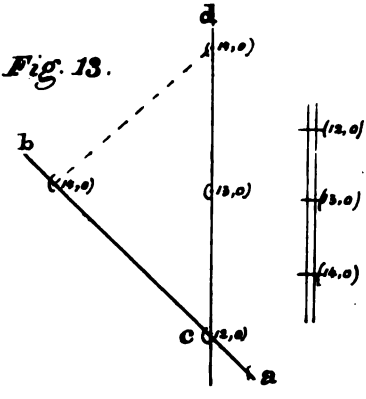


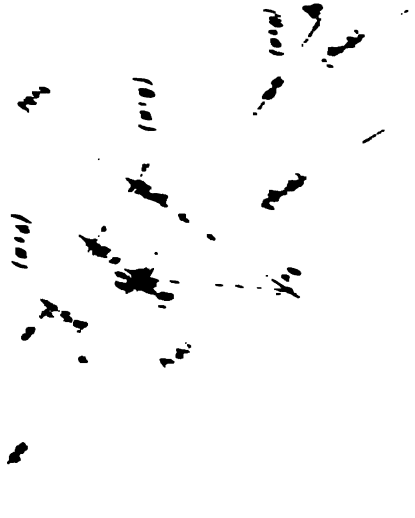
Fig. 13.

Let ab be the projection of the given line; the plane being given by its scale of declivity.

Through any point c(12,0), of the line draw a perpendicular cd to the given plane, by (Prob. 9.), and construct its scale of declivity. Find by (Prob. 1) the angle at c, between the given line and this perpendicular; this will be the complement of the angle between the plane and line.

29 Prob 12 Fig 14 To find the angle between two given planes

Fig 14



Let (s,o), and (g,o) be two horizontals in each of the planes, and a b their line of intersection.

Through any point c (s,d), of a b, pass a plane perpendicular to it, and construct Prob 3 (it will intersect these points m, and n, where horizontal (s) of this plane. Prob 7), pierces the two given planes. The line m n will be the base of a triangle, the angle at the vertex of which will be formed by the two projections of the lines between m c, and n c, and will be the required angle

24 All these surfaces may like the plane, (Art. 7.), be represented by the equations on the plane of reference of the curves that form them, or curves of horizontal planes, together with the equations of their curves; as many of these curves as may be requisite to determine all the points of the surface with accuracy.

In the more simple geometrical surfaces, a single horizontal curve with the projection of some point, or line of the surface will alone suffice. For example, the cone may be represented by the projection and reference of any curve cut from it by a horizontal plane, with the projection and reference of its vertex; a cylinder by the projection and reference of a like curve, with the projection and reference of one of its right line elements; a sphere by the projection and reference of its centre and that of its great circle parallel to the plane of reference.

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26. *Prob. 12. Fig. 15.* Through a line to pass a plane tangent to a sphere.

Let ab be the projection of the given line, (20,0) the reference of the centre of the sphere and that of its horizontal great circle, the projections of these being given.

Draw from the point c (20,0) of the given line two tangents to the projection of the great circle. The line fg, drawn through the points of contact, will be the projection of the plane of the circle of contact of the cone, whose vertex is c, with the sphere; and the point i (22,0), where fg prolonged intersects ab, will be the projection of the point

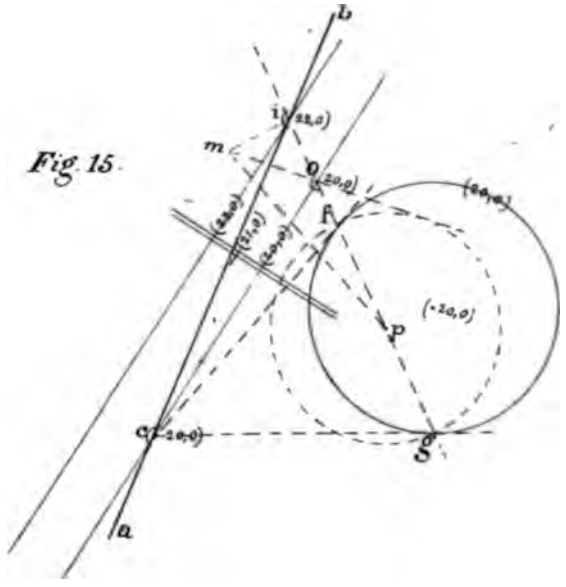


Fig. 15.

where the given line pierces the plane of the circle of contact. Drawing, from i, a tangent to the circle of contact, it, with the given line, will determine the required plane. The position of the tangent, from i, to the circle of contact may be determined by revolving the plane of the circle of contact around its horizontal diameter (20,0), until it is parallel to the plane of reference, and from the point m in this plane, which will be found in the perpendicular drawn from i to fg, and at a distance from i equal to two units, drawing a tangent to the revolved circle; the point o (20,0) where this tangent cuts the horizontal diameter (20,0), projected in fg, will be the projection and reference of a point of the required plane.

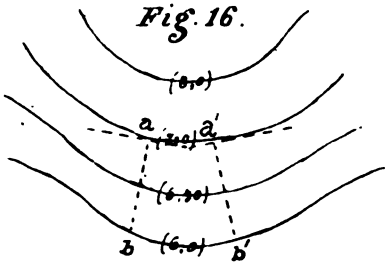
Joining the points c and o, this will be the projection of the horizontal (20,00) of the required plane. Other horizontals, and the scale of declivity of this plane, can be readily obtained by the usual methods.

The projection of the tangent from i to the circle of contact, and the point o where it pierces the horizontal plane (20,00) can be obtained by an easy calculation; by finding first the natural tangent of the angle between the line m p, drawn from m to the centre of the circle of contact, and the tangent from m to this circle; and next that of the angle between m p and the vertical m i; substituting these in the formula for the tangent of the difference of two angles, the result will give the natural tangent of the angle i m o between the vertical m i and the tangent line to the circle of contact.

27. This method of projection is more particularly advantageous in the representation of irregular surfaces which, like the natural surfaces of ground, for example, are not submitted to any geometrical law. These surfaces can only be represented by the projection of the horizontal curves cut from them by equidistant horizontal planes, and by substituting for the zone of the real surface, contained between any two horizontal curves, an artificial zone, subjected to some geometrical law of generation, which shall give an approximation to the real surface sufficiently accurate for the object in view. The usual method of doing this is to take two consecutive horizontal curves, as the directrices of the artificial surface of the zone and move a right line so as to intersect them, and, in each of its consecutive positions, be perpendicular to the consecutive tangents to one of the curves, the upper curve being

usually taken for this last condition.

Fig. 16.



If in Fig. 16, for example, (6,0), (7,0), &c. are the projections of the horizontals of a surface, the zone between the curves (6,0) and (7,0) may be replaced by an artificial surface, the position of the generatrix of which, at any point of the upper curve (7,0) will be determined by constructing the horizontal tangent at that point, as a, for example, and drawing ab perpendicular to it and intersecting the lower curve. The position of the generatrix a'b' at any other point a' is constructed in like manner.

To obtain any curve of the artificial zone intermediate to the two directrices, it will be only necessary to construct several positions of the generatrix, and to find on these the points having the same reference as the required curve. The horizontal of the surface (6,50), for example, will bisect the projections of the generatrix in its various positions.

28. Prob 13. Fig. 17. Through a given point, in a vertical plane which intersects a surface, to draw a tangent to the curve of intersection of the plane and surface.

Let a (5,0) be the given point, and ab the trace of the plane. The points where this trace intersects the horizontal

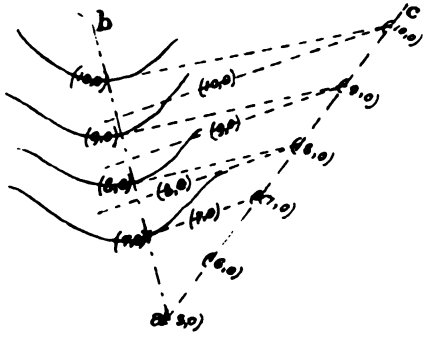


Fig 17.

curves of the surface will be the projections of points of the curve.

Let any arbitrary line as a c, be now drawn through a, and its scale of declivity be constructed; and let the horizontal lines be drawn between the points having the same references on d c and a b where the latter cuts the horizontal curves. These horizontals will generally make different angles with a c, and the one as (7,0), which makes the smallest angle with it, will determine on the curve the tangential point. To show this, construct the scale of declivity of the line thus found, of which a (5,0) is the projection of one point, and (7,0), on a b, the tangent point, another. This is most readily done, by drawing through the points (10,0), (9,0) &c; of a c, lines parallel to the horizontal (7,0), and finding where they intersect a b, in which the required tangent will be projected. Comparing now the references of the points on the line just found, and assumed as the required tangent, with the references of the points of the curve having the same projection, it will at once be evident that these two lines have only the point projected in (7,0) in common, and that every other point of the right line is exterior to the curve, and therefore this line must be tangent to the curve at the point

determined as above.

29. *Prob. 14. Fig. 18.* To construct the elements of a cone, with a given vertex, which shall envelope a given surface.

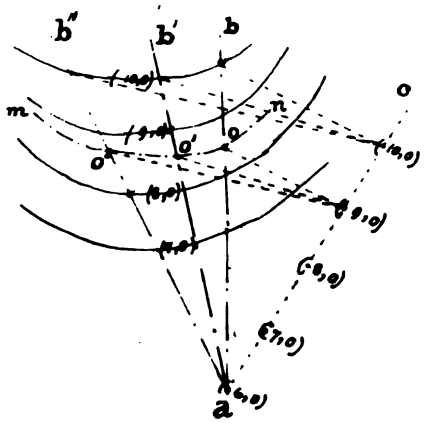


Fig. 18.

Let (10,0) d°, be the horizontals of the given surface; and a (6,0) the position of the vertex of the cone.

From a, draw ab, ab' b°, *as the traces of vertical planes which pass through the vertex and intersect the surface. Construct, by Prob. 13 the tangents, from* a *to the curves cut from the surface by the planes* ab, b°. *These tangents will be the required elements.*

30. *Prob. 15. Fig. 18.* To find the curve of intersection of a cone enveloping a given surface by a horizontal plane.

Having found, by Probs. 13 and 14, the elements of the cone, and constructed the scale of declivity of each one, by joining the points o, o', o''. *having the same reference as the given horizontal plane, as (9.0) for example; this will form a connected line* m o'' o' o n, *which will be the projection of the points where these elements pierce the given plane, and therefore the projection of the required*

intersection.

31. *Prob. 16. Fig. 19.* A limited extent of surface being given, and a point exterior to it, to find the limits within which planes may be passed through this point and lie above all the given surface.

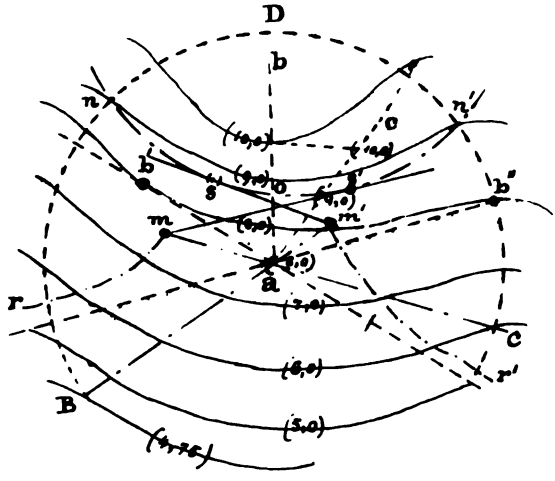


Fig. 19.

Let $a(s,o)$ be the given point; $(1,o)(9,o)$ bc, the horizontals of the given surface, the limits of which are the sector contained within the arc BDC, and the two radii aB, and aC.

Taking a as the vertex of a cone which shall envelope the given surface, the elements of this cone can be found by Probs. 13 and 14. Any plane that can be passed tangent to this cone, and which shall not intersect the surface within the given limits, will satisfy the conditions of the Prob.

From the position of the vertex of the cone with respect to the surface, it will be seen that a horizontal plane, passed through the vertex, will cut from the cone two horizontal ab', and $ab''(s,o)$; [the first of which will be tangent to the hori-

gontal curve (0,0) of the surface, and the second ab", will pierce the surface, where the limiting arc BDC cuts the same horizontal curve]; and that all the elements projected within the angles Bab' and Cab" will lie below the horizontal plane (0,0). Now, if the elements within these angles be prolonged beyond the vertex, they will form two portions of cones having the same elements as the portions below the vertex; and it is evident that any plane passed tangent to the lower portion, as b'aB, within one of these angles, will leave this portion below it, and the corresponding portion, formed by the prolonged elements, above it; and, in order that this plane shall satisfy th conditions of the problem, it must also leave the portions of the cone within the angles b'ab", and b"aC, also below it. The same reasoning applies to planes passed tangent to the portions of the cone within each of the other two angles. It is therefore evident that a plane, which shall satisfy the conditions imposed, must leave all that portion of the cone which lies above the horizontal plane (0,0) through the vertex, below it, and all the prolonged portions, corresponding to the portions below the plane (0,0), above it.

To find any such plane, let the cone be intersected by a horizontal plane, as (9,0), by Prob. 15. This plane will cut, from the portion of the cone within the angle b'ab", a curve of which n o n' is the projection; the two extreme points of this curve, within the limits; being at the points where the hou-

zontal (9,0) of the surface cuts the limiting arc; it will also cut, from each of the prolonged portions, a curve, the one m r, and the other m' r'; the extreme point m of m r being on the prolongation of the extreme element a C; that m' of the other on the extreme element aB, on the other side, prolonged. Having obtained these three curves, let tangent lines be drawn, from the points m, and m', to the curve n o n'. A plane passed through either of these tangents and through the corresponding element of the cone a s, or a s', drawn through the tangential point, will be a tangent plane to the cone; and as either of these planes will leave the curve n o n' on one side of it, and the two curves m r, and m' r', on the other, it will leave all the portion of the cone corresponding to the first curve below it, and the portions corresponding to the other curves above it, and will therefore satisfy the required conditions. The same will hold true for any tangent plane to the cone along any element drawn between the points s and s'; since the tangent drawn to any point of the curve n o n', between the points s and s', will leave this curve on one side of it, and the other two, m r and m' r', entirely on the other.

The two horizontal elements a b' and a b'' of the cone will be parallel to the assymptotes of the curve n o n'; and their lines of prolongation beyond the vertex will be parallel, in like manner, to the assymptotes of the two curves m r, and m' r'.

32. *Prob. 17. Fig. 20.* Through a given line to pass

a plane tangent to a surface.

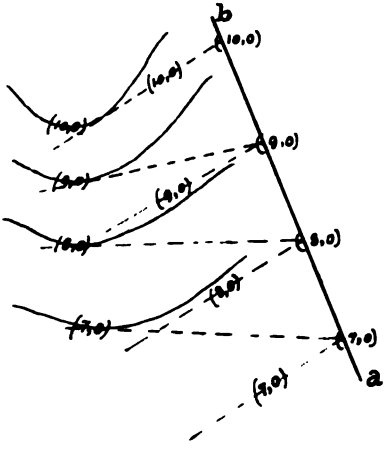


Fig. 20.

1st Set ab be the projection of the given line, and (10,0), (9,0) &c., the horizontals of the surface.

From the points on the line, as (10,0) &c., draw lines tangent to the horizontal curves having the same references; the tangent which makes with the projection of the line the least angle will, with the line, determine the required plane.

For let the horizontal tangent (10,0) be the one which makes with ab the least angle; from the other points, (9,0) &c., of ab, draw lines parallel to the tangent (10,0), these lines will lie in the plane that contains this tangent and ab, and will be horizontals of this plane; they also lie respectively in the planes of the horizontal curves (9,0), (8,0) &c.; but, since they fall exterior to the curves, it follows that their plane also lies exterior to every horizontal curve of the surface, except at the curve (10,0), where it touches the surface at the point of contact of its horizontal (10,0) with this curve.

2nd When the line ab (Fig. 21.) is horizontal, let tangents be drawn to the horizontal curves and parallel to ab.

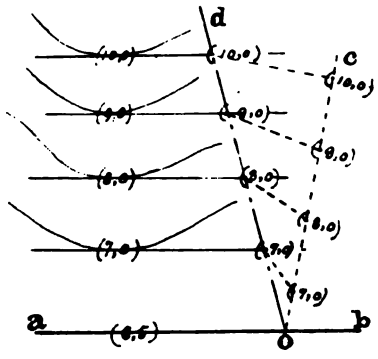


Fig. 21.

These tangents may be regarded as the elements of a cylinder which envelopes the surface, the tangent plane to which will be tangent to the surface.

To find the element of contact of the plane and cylinder, let the cylinder and given line be intersected by an arbitrary vertical plane, o d. From the point o, where the line pierces this plane, let a tangent line be drawn to the curve cut from the cylinder by the plane, by Prob. 13. The point of contact will determine the position of the element of the cylinder along which the plane, through a b, will be tangent; since the tangent to the curve o d, with the line a b, will determine the tangent plane to the cylinder.

3d. When the line a b (Fig. 22) is so nearly horizontal that tangents cannot be drawn from its points, within the limits of the drawing, to the horizontal curves.

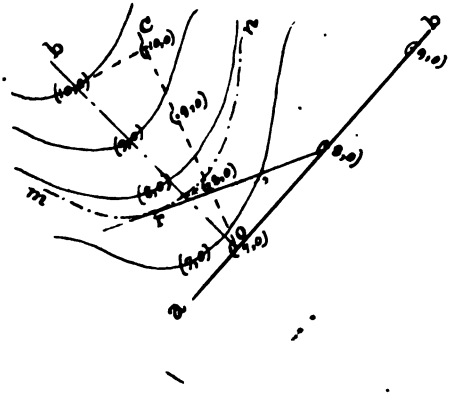


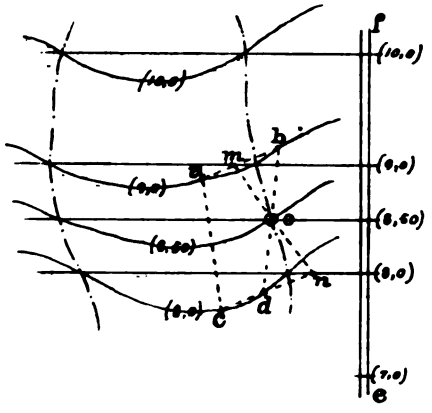
Fig. 22.

Let any point of the line, as O (7.0), be taken as the vertex of a cone enveloping the surface; a plane passed through the line and tangent to the cone will be tangent to the surface.

Find, by Probs. 14 and 15, the curve m r n cut from this cone by the horizontal plane (8,0); from the point (8,0) of ab draw a tangent to this curve. This tangent, with the line ab, will determine the required plane.

33. *Prob. 18. Fig. 23.* To find the intersection of a plane and surface.

Fig. 23.



Let (10,0), (9,0) &c, be the horizontal curves of the surface, & P the scale of declivity of the plane.

Draw the horizontals of the plane having the same references as the horizontal curves; the points of intersection of these lines, in their respective planes, will be points of the required intersection.

When it is desired to find a point of the curve of intersection intermediate to two horizontal curves; if the reference of the required point is fixed, it will be necessary to construct (Art. 27) the horizontal curve of the surface, and the horizontal of the plane having this reference; their intersection will

give the required point. If the reference of the required point is not fixed, select on the upper and lower curve an arc of each horizontal curve such that the chords ab, and cd of these arcs shall be parallel, the arcs being so small, and so placed, that the trapezoid a d may be taken as the portion of the gone corresponding to the arcs, and have the required point some place on the side b d. Now a b and c d may be regarded as the horizontals (9,0) and (8,0) of the trapezoid. The points m, and n where they cut the corresponding horizontals of the plane being joined, the line m n will be the intersection of the plane and trapezoid, and the point o, where this line cuts b d, will be the one required.

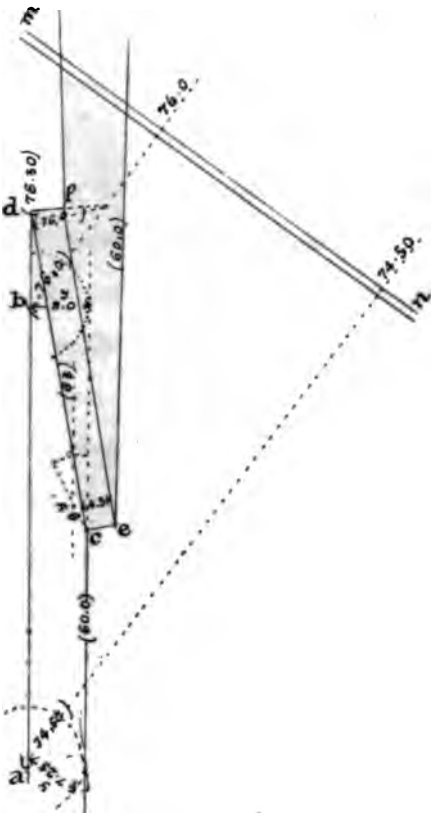
The following problems will aid as illustrations of the preceding subject in its application to the determination and delination of lines and surfaces.

34. *Prob. 19. Fig. 24.* The plane of site of a work, the exterior line and scale of declivity of its terre-plein being given; to construct the plane of the rampart-slope and its foot; also a ramp of a given inclination along the rampart-slope leading from the plane of site to the terre-plein.

Let a (74,50) and b (76,0) be the references of two points on the exterior line of the terre-plein, and m n its scale of declivity; let the rampart-slope be $\frac{1}{2}$; the declivity of the ramp $\frac{1}{3}$, its width 4,30 yds; and the plane of site be horizontal and at the ref. (60,0).

$\frac{2}{3}$

Fig. 24.



The foot of the rampart-slope lying in the plane of site will be horizontal and will be determined, (Prob. 6. Fig. 8) by finding the line of the slope at the ref. (60.0)

Having the two bounding lines of the rampart-slope, the inner line c d, of the ramp is constructed, by assuming a point c, on the foot of the rampart-slope, as the point of departure, and determining the line of $\frac{1}{3}$ drawn from c on the rampart-slope by (Prob. 3. Fig. 8.). Having found this line, which is also the line of greatest declivity of the ramp, the exterior line e f of the ramp is drawn parallel to it, and at a distance 4,30 yds equal to the width assumed for the ramp. The horizontals of the ramp will be perpendicular to these two lines. The foot of the ramp c e, will be a horizontal

line, drawn through the point of departure. The top of it d f, will be determined (Prob. 7. Fig. 9.) by finding the intersection of the ramp and the terre-plein, one point of which will be the point d (76,30) the intersection of the inner line of the ramp and the interior line of the terre plein.

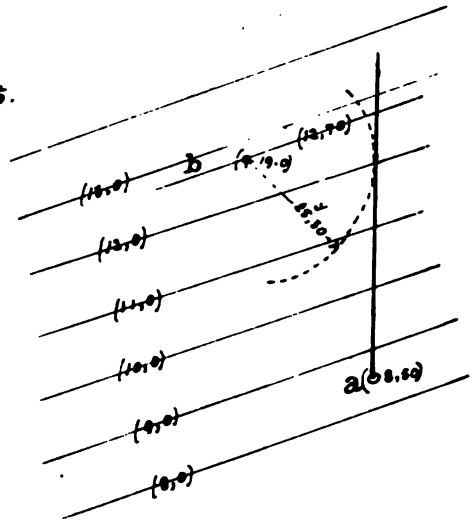
The ramp is terminated on the exterior, by passing a plane through its exterior line e f having the same slope as the rampart slope. This plane will intersect the plane of site in a line parallel to the foot of the rampart slope, and the terre-plein in one parallel to the exterior line of the terre-plein.

35. Prob. 20. Fig. 8. The projections and references of two points being given, to draw a horizontal line through one, so that the horizontal distance between this line and the other point shall be to the vertical distance between them, in a given ratio.

The solution of this problem is evidently the same as that of Prob 6. Art. 18. For let a (12,0), and b (14,0) be the given points. To draw from b a horizontal line with the required conditions, it will be only necessary, from a to describe an arc, the radius of which is to the difference of reference of a and b in the given ratio, and then, from b, to draw a tangent to this arc, which will be the required line.

36. Prob. 21. Fig. 25. Two points being given, the one in

Fig. 25.



an inclined plane, and the other above the plane, to determine a plane, passing through the last point, such, that the vertical distance between the two planes at any point, shall be to the horizontal distance between this point and the projection of the intersection of the two planes, in a given ratio.

Let a (8,50) *be the point in the inclined plane given by its horizontals* (8,0), (9,0) &c; b (19,0) *the other given point; and the given ratio* $\frac{1}{4}$.

If from b *an arc be described, with a radius the ratio of which to the height of* b *above the given plane is the one imposed, and a line be drawn from* a *tangent to this arc; this tangent will be the projection of the required intersection, and, with the point* b, *will determine the required plane.*

It is evident that the conditions of the Prob. are satisfied for the point b *by the construction; and it is easy to prove that they obtain for the vertical distance*

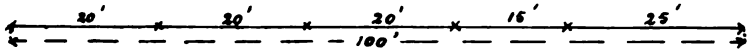
between any other two points of the planes having the same projection

37. Observations on the means for obtaining accuracy in drawings.

The first requisite in all drawings intended to represent not only the outline of the forms of objects, but to afford the means of determining the exact dimensions of each part, is minute accuracy both in the geometrical constructions, and in writing down all letters and numbers which serve either as references, or to give the dimensions.

To attain this end so far as regards the geometrical part judgment is to be exercised in the selection of the means for establishing on the drawing the positions of the various points which are either given or to be found; as one method although in theory as correct as some other may not in practice be found to yield as satisfactory results. Attention to the following remarks will serve both to illustrate the meaning here intended, and to give some simple practical methods.

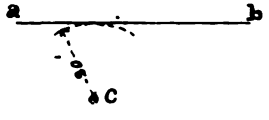
1st In setting off several distances, along a line, whether equal, or unequal, the most accurate method is to commence by first setting off the entire distance, and then the several parts; taking care to verify, from the scale, the aggregate of the several partial distances; thus in the annexed Fig.; where the aggregate of all the partical distances is 100 feet,



commence by setting off the entire distance 100 feet; next 60' which is the sum of the three equal distances 20'; then vertify the remaining 40' by the scale; next set off the 25', and vertify the 15' remaining &c.

2nd When a distance to be set off is so small that it cannot be laid down with accuracy by the points of the dividers, the following method may be employed; set back, from the point from which the required distance is to be set off, any arbitrary distance, then set forward, from this last point, a distance equal to the sum of this arbitrary distance and the one required: thus in the annexed Fig. where 2' is to be set off from a towards C, b ---20'--- $\overset{2'}{\underset{a}{\leftrightarrow}}$ c, set back from a say 30' to b, then from b 32' to c.

3d In setting off a point at a given perpendicular distance from a line, instead of drawing a perpendicular, in the first place, to the line, it will mostly be found more speedy, and more accurate, to take off from the scale the given distance, in the dividers, and, setting one point on the paper, bring the other so that the arc described by it, with the given distance as a radius, shall be tangent to the line; thus is the annexed Fig., wishing to set off c at 20' from ab, take 20' in the dividers, and, by the eye, find where one point must be placed so that the other describing an arc will touch ab. This method will be found



intersection of two lines arbitrarily chosen, such a position should be assumed for the arbitrary lines that they shall not form a very acute angle, as in that case their point of intersection might not be determined by the eye with accuracy. For example, in erecting a perpendicular to a line at a given point, and in like problems, in which points are found by the intersections of arcs of circles, it will be usually most convenient, and best, to take for the radii of the arcs the distance between their centres, as the angle between the tangents to the arcs at their point of intersection will then be 60°, which is sufficient to give accurately the point where the lines cross. In cases, like Figs. 11, 12 &c., (Arts 20, 21, &c) the arbitrary lines ab, a'b', &c, should be so chosen as to intersect the horizontals nearly at right angles and so, also, that the resulting lines, by which the points O, O' are determined, shall not intersect in too acute an angle.

In all such cases of determining points, and even where a point is pricked into the paper by a sharp point, it will be found well to mark the point thus ⊙, ⊠, by a small circle drawn around it with the lead pencil, as this will present the point with more distinctness.

6th In determining a portion of a line, by the construction of two arbitrary points, the points should be so chosen that the portion required may fall between them and not beyond them. In (Fig. 10) for example, if the

required portion of the line of intersection of the planes extended on either side, beyond O, or O', or beyond both; the lines ab, cd &c. should be so chosen as to bring O and O', as far apart, at least, as the length of the required portion of the line which they serve to determine.

7th. No means of verifying the accuracy of the construction of points, or lines, should be omitted. In (Fig. 9) for example, other corresponding horizontals should be drawn, and, if the line of intersection determined by the two points first found in correct, their points of intersection also will fall upon it. In (Figs. 9, 10,), the scale of declivity of the line of intersection being determined, the references of the points, where it intersects the scales of declivity of the planes, should be the same as the same points on the scales, if the line has been accurately determined. A general and minute verification of all the parts of the drawing should be made before any portion of it is put in ink.

8th. Neatness is a not unimportant element in the attainment of accuracy in drawing. A few minutiæ, when attended to, will subserve this end.

That part of the paper on which the draftsman is not working should be kept covered with clean paper, pasted on the edge of the board, so as to fold over the drawing; the parts which are finished should be similarly protected.

Before commencing the daily work the paper should be carefully dusted, and the scales, rules and triangles be carefully wiped with a clean dry rag.

As few lines of construction as possible should be drawn in pencil; and only that part of each which may be strictly necessary to determine the point sought. As, for example, where a point is to be found by the intersection of two arcs of circles; when the position of the point can be approximately judged of by the eye, only a portion of one arc, which will embrace the point, may be drawn, and the point where the second arc would intersect the first be marked, without describing the arc. In (Fig. 10.) instead of drawing the entire lines ab, cd &c, it would be simply necessary to mark the points only where they cut the horizontals; and, in like manner, the points O and O' might be marked, without drawing the entire lines.

No more of any line of the drawing should be made in pencil than what is to remain permanently in ink.

9th In inking the lines the following directions will be found useful.

Efface carefully all pencil lines that are not to be inked; and those parts of the permanent lines which are not to remain, before commencing to ink.

When right lines are tangent to curves, put in ink the curve before the right line; draw all arcs of equal radii

at once, one after the other; if several arcs are to be described from the same center, it will be well to put a thin bit of quill over the point for the end of the dividers to rest on, to avoid making a large hole in the drawing.

If the drawing is not to be coloured with the brush, all the lines of one colour should be put in before commencing on those of another.

If one of the bounding lines of a surface is to be made heavier than the others, its breadth should be taken from the surface they limit and not be added to it; and when the heavy line forms the boundary of two surfaces, its breadth must be taken from the one of greatest declivity.

10 When the drawing is to be coloured, all lines that are not to be black may be put in first with black, making them very faint, so that they may receive their appropriate colours after the drawing is otherwise completed.

No heavy line should be put in until the work with the brush is completed.

When all the lines are in, the drawing should be thoroughly cleaned with stale bread-crumb; and then have several pitchers of water dashed over it, the board being placed in an inclined position to allow the water, coloured by the ink lines, to escape rapidly, and not to discolour the paper.

11 In using the brush, whether for flat tints, or graded, the requisite depth of tint should be reached by a number

of faint tints laid over each other; this is especially necessary in laying tints of blacks, browns and reds.

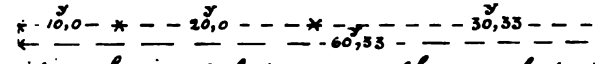
To obtain an even flat, or graded tint, on dry paper is very difficult for a beginner. The best plan for this is, first to wet with a large brush, or clean rag, the surface on which the tint is to be laid, then, with a slightly moist rag, clear the surface of water, and before the paper has time to dry lay on the tint. With this precaution, the heaviest tints of chinese ink, the most difficult of all to manage on dry paper, can be neatly laid down.

12th The lettering and numbering of a drawing should be in ordinary printed character; this is particularly requisite in the numbering, to avoid misapprehensions which might arise from individual peculiarities in writing numbers.

As has been already remarked, references are written in black, within brackets which, when practicable, embrace the point referred to. When not practicable, a small dotted line may lead from the point to the reference. thus (26.50). All references, except those of horizontals, are written parallel to the bottom border of the drawing, for the greater convenience of reading them. References of horizontals are written upon and in the direction of the horizontals. The unit used for the references is the foot, and its decimal divisions of hundredths;

but to distinguish references from other numbers the designation of the unit is omitted.

All horizontal distances between points are written upon a dotted line drawn between the points, with an arrow head at each end; where several partial distances in a right line are marked, it will be also well to mark the total distance, the latter may be written above or beneath the former. thus

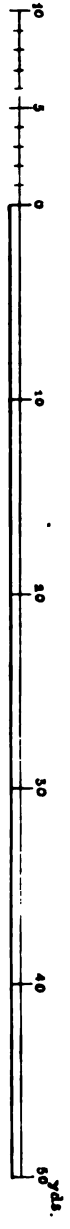


In writing horizontal distances, the usual designation of the unit is always written thus ˣ for yards, ' for feet, &c. All the numbers must be expressed in the same unit; the fractional parts being in decimals.

References and horizontal distances cannot be too much multiplied, in order to avoid misapprehensions, and the results of errors of construction, as well as to save the time that would be taken in applying dividers to the drawing, to find, from the scale affixed to it, the dimensions of any part.

A scale very accurately constructed should be affixed to the drawing before it is cut from the board; so that the shrinkage of the paper, which is about $\frac{1}{500}$, may affect all the parts equally, and the scale thus be made to correspond to the real lengths of the lines on the drawing. The scale should be divided according to the decimal system, as being most convenient for counting

off. The first division of the scale should furnish the units and also their decimal parts, if the scale bears that proportion to the true dimensions of the objects represented which will admit of these divisions. This first division is numbered from right to left the zero point being on the right, the 10 point on the left; the succeeding divisions, to 50 inclusive, should each be equal to the first division containing ten units each. The remaining divisions may contain fifty units each. It will be readily seen that any number of tens, units, or fractional parts of a unit can be readily taken off from the scale by the dividers. The scale should be long enough to give the dimension of the longest line on the drawing.



The proportion which the scale bears to the true dimensions of the object should be written above the scale; thus Scale one inch to ten yards, or $\frac{1}{360}$. And the designation of the units of the drawing should be annexed to the last division on the scale, as yds. for yards; ft. for feet. &c.

Elements of Permanent Fortifications.

General Considerations and Definitions.

1. The object as well as the general principles of both Temporary and Permanent Fortification are the same; the difference between them consisting rather in the degree of resistances to be obtained, and in the means by which each attains its object.

The former decides on its measures, most frequently, from a hasty glance, employs for its ends the means most readily found at hand, and proposes no higher degree of resistance than to check an open assault, by rendering every approach of the assailant extremely perilous, and forcing him to purchase at a bloody cost each advantage. It finds its applications in the hourly changing events of of an army in motion; its creations ceasing to be of farther importance to the assailed so soon as the scene of conflict is shifted.

The latter, on the contrary, weighs deliberately all its conceptions, and determines on nothing but upon a thorough investigation; selects its means with minute

care, and with a view to great durability and strength in its designs. It proposes not only to foil an assailant in every attempt at open assault, but to constrain him to extreme circumspection in every movement, leaving him no other road, to gain his ends, but the tedious, laborious and costly operation either of a Siege, or a Blockade. It looks, in its plans, only to those points which are of permanent importance to the safety of the state, as the great avenues of its inland and maritime frontiers, which it secures from the peril of a sudden irruption of an enemy by the constant presence of an armed force placed behind the bulwarks of its erection.

2. All the defences of a position having these characteristics of permanency and strength are termed Permanent Fortifications, or Permanent Works. If the position thus secured is an inhabited one, as a city, or town, it receives the appellation of a Fortress. If the work is destined to receive no other inhabitants but the troops for its defence it is termed a Fort; and its defenders are termed the Garrison.

3. To effect the object in view in the erection of permanent works, the point to be defended must be enclosed within an unbroken line of fortification, of such strength of profile as to frustrate all attempts to break through it with the means usually employed by an assailant in an

open assault, and have the different parts of its plan so combined that an enemy cannot approach it on any point without being completely exposed to its fire.

4. As the relief and command that can be ordinarily given to temporary works are insufficient for these purposes, engineers have been obliged to give greater strength to the profiles adopted for permanent works; and, to this end, have elevated their parapets above the surface of the site occupied, placing them on a high and broad mound of earth, termed a Rampart, (Pl. I. Fig. 3.) from the top of which the assailed have a commanding view, and can sweep by their fire all the ground exterior to the defences; whilst they have the shelter and usual advantages afforded by the parapet, which borders the side of the rampart towards the enemy.

5. Circumjacent to the rampart a wide and deep Ditch is also placed, which subserves the same ends as the like construction in temporary works; furnishing the earth for the rampart and parapet, and presenting with them an obstacle insurmountable by ordinary means.

6. The top of the rampart in the rear of the parapet is termed the Terre-plein; it affords convenient space for the troops, materiel and necessary manoevres for the defence. The earth of the rampart descends, by a uniform declivity, termed the Rampart-slope, from the terre-plein to the level

behind it, termed the Parade. Inclined planes termed Ramps, which are usually placed against the rampart-slope, connect the levels of the parade and terre-plein, and serve as the lines of communication between them.

7. The face of the ditch towards the rampart is revetted with a wall of masonry which rises to the level of the foot of the exterior slope of the parapet, and sustains the pressure of the rampart and parapet. This wall is termed the Scarp-wall, or Scarp-revetment; and the face of it towards the ditch the Scarp.

The scarp-wall is finished at top by a thin, broad, flat stone, termed the Coping or Cordon, which projects beyond the face of the wall.

The line where the scarp, if prolonged, would intersect the top of the coping is termed the Magistral-line, or simply Magistral.

The top portion of the coping, from the foot of the exterior slope outwards, is termed the Berm.

The face of the ditch from the rampart is usually revetted in the same manner as the one opposite. The wall is termed the Counterscarp-wall, and its face towards the ditch the Counterscarp.

8. The entire line of fortification, formed by the rampart and parapet surrounding the parade, is termed the Enceinte, or Body of the Place.

The line forming the enceinte, like the corresponding

one in enclosed temporary works, may be of any polygonal shape. The form most generally adopted by engineers is the bastioned one, as this when its elements are properly combined, brings its fire to bear more thoroughly on every point beyond the scarp of the enceinte than any other, and thus satisfies in the best manner one of the essential conditions imposed on permanent works.

9. A permanent work composed of an enceinte and its ditch alone, although satisfying the two essential conditions imposed upon every such structure, still leaves much to be desired, in the degree of resistance which a well disciplined garrison ought to offer, when provided with all requisite facilities for the display of their courage and skill. Limited to these two elements, the work is reduced to a resistance almost purely passive, and its garrison to a state of partial inactivity. Having no points of cover beyond the ditch, the troops cannot engage in any exterior operations without great peril; for not only would they, under such circumstances, be exposed to the full sweep of the enemy's fire, so soon as they should emerge from the shelter of the counterscarp; but, if hotly pressed in retreat, they might run the risk of being made prisoners under their own guns, from the difficulty they might meet in placing, with sufficient promptitude, between themselves and their pursuers, a deep and wide ditch, accessible only through steep, narrow and

incommodious outlets.

Besides these restraints placed upon the exertions of the garrison of a work of this character whilst its walls are still intact, another, not less disheartening, is presented so soon as an enemy has succeeded in making a breach in them. Unprovided with a point of security into which they can retire after they are forced to yield the enceinte, the garrison are exposed to the more fearful peril of finding themselves at the mercy of the enemy in the fury of the onslaught, should they make an unsuccessful effort to defend the open avenue he has at length made for his columns, after weeks of toil, privation and hourly loss of life.

To keep up therefore the morale of the garrison, or, in other words, to give them a well founded reliance on their own powers to cope with their assailants successfully hand to hand, additional defences have been devised by engineers, by which confidence is given to the troops, emboldening them to sally beyond their works and attack their enemy with audacity and vigor, and when finally reduced to their last field of action, not to retire from it until they have struck one more blow for honor, however hopelessly for victory.

The additional defences arranged for these purposes are termed Out-works and Interior Retrenchments. The first are exterior to the enceinte and connected with it by intimate relations of defence. The second are dis-

positions, made within the enceinte, which must be carried by the enemy, after he has forced his way through the breach, before the garrison can be obliged to lay down their arms. They both serve, if properly employed, to protract the defence and gain for the garrison honorable terms of capitulation.

10. The out-work most indispensable to a garrison determined on an active, vigorous defence is the one termed the Covered-way. This is a covered position, bordering the ditches of the enceinte and other out works, if there be any, formed by an embankment which rises, at a few yards beyond the counterscarp, to a height sufficient to cover troops in its rear, and descends by a gentle, uniform slope, or glacis to the level of the site on the exterior. On the interior, the embankment is arranged, for the service of fire arms, like other parapets.

The space thus enclosed can be safely occupied by troops at all times; and they can be assembled in it in sufficient numbers to make a strong sortie on the enemy. If repulsed, they can promptly regain a safe cover in it; knowing that the pursuit cannot be made up to it without murderous loss to the pursuers, both from the fire of the troops left in the covered way, to cover the retreat of those without, and from that of the works in the rear of the ditches, by which the glacis and all the ground beyond can be perfectly swept.

11. The principal out-works besides the covered-way are

1st the Demi-lune, a work in the form of a redan, having usually a revetted scarp and gorge of masonry, which is placed in advance of the enceinte, and covering the curtain and shoulder angles in a bastioned front.

2nd The Tenaille, a low work, also with revetted scarp and gorge, placed on the prolongations of the bastion faces, between the flanks and curtain, but separated from each by a narrow ditch. Its main object is to mask the masonry of the curtain and flanks from the enemy's artillery, and to cover a postern, or sally-port, leading to the ditch, under the rampart of the curtain.

3d The Counter-guard, work in shape like a redan with revetted scarp and gorge. It envelopes the two faces of the bastion, to which its two faces are nearly parallel. It covers the bastion faces before which it is placed, and protracts the defence, as the enemy cannot make a breach in the faces of the bastion until he has got the counter-guard in his possession.

4th Redoubts, or Reduits, these are small works placed within some one of the main out-works, as the demi-lune &c. They strengthen the works in which they are placed, and protract the defence. They receive their names from the works in which they are placed, as the Demi-lune-redoubt. &c.

12. The Interior Retrenchments are placed on such points

as are exposed to be breached by the enemy's artillery, and are intended to cut off these parts from that portion of the enceinte not so exposed.

They are of various forms, being adapted to the position they occupy, and the degree of resistance to be offered.

When a considerable command is given to an interior work over the one within which it is placed, with a view of obtaining a plunging fire on points which the enemy may occupy on the exterior, it receives the name of a Cavalier.

When a work is detached from the enceinte, and is organized to receive the garrison and rely on its own resources after the main work has fallen, it receives the appellation of a Citadel

13. Works placed beyond the covered-ways of the enceinte and its out-works, but connected with them in a general system of defence are termed Detached-works.

14. The portion of the enceinte and its out-works embraced between the capitals of two adjacent salients, is termed a Front of Fortification; and the particular combinations adopted in establishing the proportions which the various parts bear to each other, as well as their relations of defence, constitute what is termed a System of Fortification.

Systems are frequently named after the engineer

with whom they orginated. Thus we say Vauban's System, Coehorn's System, &c to designate the combinations usually adopted by these engineers.

Bastioned Systems.

The general principles and rules of practice of the Art of Fortification are the results of experience derived from the means employed in the attack and defence of intrenched positions. These results have been gradually embodied in the form of precept, and, from time to time, reduced to systematized modes, by the more eminent practitioners of the Art, and in this shape delivered by them to their professional successors. This method of transmission has been attended with some draw-backs, but such only as are inherent in all organized associations of men for perpetuating any branch of art; one, a bias to routine, growing out of a too bigotted deference to authority and adherence to old ways; another, an esprit de corps which, whilst it tends to elevate the character of the profession, is, at the same time, prone to foster a spirit of exclusiveness, and to repel, as attacks on the professional character of the body, every suggestion coming from abroad; and, too frequently, to discard, without due examination, propo-

sitions from within that militate against long established notions, unless they have received the stamp of some oracle of the moment. But these evident defects are not unaccompanied by as evident advantages. A barrier is raised against innovation which, whilst it stays the enthusiastic, or ignorant projector, is not an impassable obstruction to him, who assails it with the weapons of knowledge and sound argument. If it retards improvement, it also narrows the area of rash experiment, and saves the state from much wasteful expenditure. And, in the end, it surely eliminates all errors of principle and practice, and yields for a result only what has stood the ordeal of oft repeated tests, and the combined scrutiny of many enlightened minds.

It is to considerations of this nature, that is, in a great degree, due the hold that the works of a few masters of the Art of Fortification have taken of the professional mind; and which has given to them a character of permanency and authority nothwithstanding many acknowledged important defects. Among the most noted of these works, from the controlling influence they have exercised upon the Art throughout the civilized world, are the Systems of Vauban and of Cormontaingne, French engineers who, to high attainments in science, united a wide range of practice, both in the construction and in the attack and defence of fortified places.

So sound were the views of these eminent men, and such has been the respect with which they have been regarded by their professional successors, that their works are still looked upon as the safest guides to the military engineer, and they constitute the basis of the elementary instruction in fortification usually given in the military schools in the present day.

15. **Vauban's 1st System.** Vauban has left examples of three different systems in the places planned by him. The fortress of New Brisac is fortified after his third method; those of Landau and Befort after his second, but the greater part of the places fortified by him are planned according to his first, or earliest method, as this has been adopted for the basis of the art as now practised, a description of it alone will be requisite for the object of this Course.

16. In the profile of the 1st system, (Fig 1. Pl. I) the scarp wall is 36 feet high, its slope being five perpendicular to one of base; surmounting this is another wall from 4 to 6 feet high, the object of which is to sustain the exterior of the parapet. The parapet is 18 feet thick, the superior slope being 1/9; the interior crest is 8 feet above the terre plein, which is 42 feet in width. The mean command of the interior crest above the site is about 26 feet. The bottom of the ditch is about 17½ feet below the

site.

17. In the plan or tracé, (Fig. 2. Pl. I.) the magistral is taken as the directing line; the exterior side is 360 yards; on the perpendicular of the front a distance of 1/6 the exterior side is set off; lines drawn through this point and the extremities of the exterior side, determine the directions of the faces, and the lines of defence; from the salients a distance equal to 2/7 of the exterior side is set off, which gives the lengths of the faces, and the positions of the shoulder angles; the flank is drawn by taking the opposite shoulder angle as a centre, and with a radius equal to the distance between the shoulder angles describing an arc to intersect the line of defence, the chord of this arc is the flank; the curtain is drawn by joining the extremities of the flanks. By this construction the flanks will be about 54 yards; the curtain 146; and the lines of defence 267, the length of these being determined so that the salients of the bastions can be defended with the rampart gun, or wall-piece.

18. In many of the places constructed before Vauban's time there was a low work, enveloping the enceinte and connected with it called a fausse braie. This work, which had many defects, was suppressed by Vauban, who was the first to use the tenaille in its place. The tenaille has many valuable properties; it covers the arched communication, or postern under the curtain; masks the masonry of the curtain

and flanks, so that a breach cannot be made in them, and in this way prevents retrenchments, resting against those parts, from being turned: a place of arms is formed between it and the curtain, where troops can be assembled for sorties in the ditches; finally: its fire sweeps the ditch and counterscarp, and helps to cover the retreat of troops from the other outworks. The tenaille is separated from the curtain by a ditch 10 yards wide, and from the flanks by ditches of 6 yards. The form of the tenaille as used by Vauban was variable; in some cases he made it with a curtain and two small flanks parallel to those of the enceinte; in others it consisted simply of two wings placed on the prolongations of the faces; and finally, he gave it the form in Fig. 2) with a small curtain and two wings; which is the one at present most generally adopted. The relief of the tenaille is so arranged as not to mask the fire of the flanks on the ditch of the enceinte along the faces; for this purpose Vauban places its interior crest on a level with the site, or a little below it.

19. Vauban followed no invariable rule in regulating the dimensions of the enceinte ditch; it's most usual width at the salients of the bastions, where the counterscarp is an arc of a circle, is about 36 yards; the rest of the counterscarp is tangent to this arc, and directed upon the opposite shoulder angles.

20. Vauban increased the dimensions of the demi-lune which had been used previous to his time. The object of this work is to secure the gates of the place from a surprise; to mask from the enemy's batteries, the flanks and curtain of the enceinte; and give cross fires on the salients of the bastions. The plan and dimensions of the demi-lune vary also in Vauban's works. Its magistral is generally laid out by taking a point on the bastion face at 10 yards from the shoulder angle, and drawing a line from this point to the perpendicular of the front; so as to make the face of the demilune equal to 2/7 of the exterior side. The parapet of the demi-lune is the same as that of the enceinte; its command is 3 feet less than that of the enceinte. All the outworks in this system are commanded by the enceinte; the outworks most advanced being also commanded by those in rear.

To strengthen the demi-lune, and secure for the troops entrusted with its defence a safe retreat when it is carried. Vauban placed in it a small redoubt. This work in some instances was only a simple crenated wall with a ditch in front; sometimes it was made of earth and after the commencement of the siege.

The ditch of the demi-lune is generally about 24 yards wide, and of the same depth as that of the enceinte its counterscarp and that of the enceinte forming a con-

tinuous wall.

21. The covered way envelopes the entire counterscarp. Vauban placed a high value on this work, which, to use his own words, "costs less to the defence and more to the assailant than any other work." The covered way prevents all access to the ditch, by a strong fire of musketry, which sweeps all the exterior ground; it is a secure position where troops can be assembled in safety for sorties; it covers the retreat of troops from the exterior into the other works. The general width of the covered way is 12 yards; the portions of it in front of the counterscarp at the bastions and demi-lune are called the salient places of arms. The re-entering formed by the covered ways of the bastion and demi-lune is enlarged and termed a re entering place of arms. To set out this work, two points are taken, at 20 yards from the re-entering angle, made by the interior crests of the covered ways of the demi-lune and bastion, and upon these crests, and from these points as centres, with radii of 24 yards arcs are described, the point of their intersection being joined with the centres gives the crests of the re entering place of arms. The parapet of the covered way is terminated in a glacis, the foot of which is from 40 to 50 yards from the interior crest.

To close the places of arms, and enable the troops to defend the covered way foot by foot, traverses

of earth formed into parapets are placed at the places of arms. Defiles or passages of 4 feet are left between the traverses and the crest of the covered way, for the circulation of the troops. The covered way is palisaded to prevent surprise.

22. The communications constitute an important part of every system. In Vauban's ramps are made to ascend from the plane of site to the terre plein. A postern is made under the curtain, to communicate from the interior with the ditch; another postern is made under the tenaille, to lead to the demi-lune; a double caponniere, which is a passage covered on each side by a parapet terminated in a glacis towards the ditch, covers the communication through the ditch to the gorge of the demi-lune; single caponniers are placed in the ditch of the demi-lune, and cover the troops from the enemy's fire through it's ditch; stairs are placed at the gorges of the tenaille and demi-lune, and along the counterscarp at the places of arms, to ascend from the ditch to the terre pleins of those works. To communicate with the exterior narrow openings are made in the faces of the re-entering place of arms, to lead from the terre plein to the glacis; they are called Sortie passages or Sally ports, and are closed by barriers.

23. Cormontaingne's System. Cormontaingne holds the next rank to Vauban as an engineer. He studied with great care the works of the latter, and applied him-

self chiefly to improve such parts of his first system as appeared from experience to be defective. Observing from the great height given by Vauban to his scarp walls that they might be easily breached from a distance, Cormontaingne suppressed the small wall supporting the parapet, (Fig. 3. Pl. I.) and diminishing the height of the scarp wall he placed the top of it on a level with the crest of the glacis. He adopted as a principle, that all masonry should be masked from the fire of the enemy's batteries at a distance; and this he effected by placing the crest of the glacis as high at least as the top of the wall to be masked. This is one of the most important modifications which Vauban's profile owes to Cormontaingne.

24. The modifications of Vauban's trace (Fig. 4. Pl. I.) are different in the various works of Cormontaingne; but the following he indicates in his memoirs as the most perfect. The exterior side is 360 yards; the perpendicular 1/8; the faces of the bastions 1/3 of the exterior side; the flanks are 40 yards and are so placed that the curtain shall be 120 yds; this combination makes the lines of defence somewhat less, and the bastions larger than in Vauban's system.

The dimensions of the enceinte ditch are so regulated by Cormontaingne as to furnish earth sufficient for the embankments. It is 28 yds, wide at the salient, and from 2 to 4 yds, wider opposite the tenaille; this admits the entire fire of the flanks to sweep the ditch.

25. The tenaille is made with a curtain and wings; a ditch 10 yds. wide being left between it, the curtain and the flanks.

26. Cormontaingne placed little value on small demi-lunes, as they form but slight and therefore weak re-enterings before the bastions, and consequently retard but little the enemy's attack upon the bastions; besides this a small demi-lune covers but very imperfectly the shoulder angles of the bastions. To remedy these defects, his demi-lune is so laid out that the prolongations of the magistrals of its faces will intersect the bastion faces at 30 yds, from the shoulder angles; the lengths of its faces being 120 yds.

By thus enlarging the demi-lune, sufficient space is gained to place a strong redoubt in its interior. The defence of the demi-lune may be made with more obstinacy from the support it receives from the redoubt; and the enemy will be obliged to carry the redoubt before he can assault the breach he may have made in the bastion face, as this breach is seen in reverse by the fire of the flanks of the redoubt.

27. To circumscribe as much as practicable the space in the demi-lune which the enemy after he gains it, requires for his works, the extremity of the demi-lune terre plein, which is also the top of the counterscarp of the redoubt, is drawn at 20 yds, from the magistral of the face,

the ditch of the redoubt is 10 yds. wide, and the magistral of its face is parallel to the counterscarp. By this arrangement the ditch of the redoubt is well flanked by the face of the bastion near the shoulder angle. To lay out the flanks of the redoubt, the counterscarps of the enceinte are prolonged to intersect the perpendicular of the front, from this point of intersection a distance of 20 yds, is set off along each counterscarp, the two points thus obtained are joined by a right line, which is the gorge of the redoubt; from the extremities of the gorge two lines are drawn parallel to the capital of the demi-lune, these lines limit the terreplein of the flanks; the magistrals of the flanks are drawn parallel to and at 16 yds, from the last lines. The ditch of the demi lune is 20 yds wide; its depth is the same as that of the enceinte.

28. The general width of the covered way is 10 yds. Cormontaingne enlarged considerably the re-entering place of arms, to which he added a redoubt with a revetted scarp and counterscarp. The addition of this redoubt is a great improvement upon the covered way of Vauban, who indicates in his works small redoubts of earth, or tambours of wood, for the same purpose. Cormontaingne's redoubt increases the strength of the covered way; the troops assembled in the covered way for sorties are secure under its fires; it sees in reverse, and protects any breach made in

the face of the demi lune; finally, it serves, in connection with the extremity of the demi-lune, to cover the opening left between the flanks of the bastion and the wings of the tenaille, through which if a breach was made in the curtain, the interior retrenchments, resting upon either the flanks, or faces of the bastion, could be turned.

29. To lay out the interior crests of the re-entering place of arms, two points are taken on the counterscarps of the bastion and demi lune at 54 yds, from their point of intersection, from these points as centres, with radii of 60 yds, arcs are described, whose intersection joined with the centres gives the direction of the faces. The magistral of its redoubt is found by a similar construction; distances of 46 yds, being set off along the counterscarps, and the faces being drawn from these points so as to be 36 yds long. The ditch of the redoubt is 5 yds, wide and 2½ yds, deep.

30. Traverses are placed along the covered way; to close the places of arms, defend the covered way, and intercept projectiles fired in ricochet.

31. The crest of the glacis is broken into a cremaillere line to allow room for the defiles of the traverses. The short branches of the cremaillere throw a fire on the salients of the covered way; the positions of the long branches are so taken that the defiles may be seen, and

swept by the fire of the works in their rear.

32. Cormontaingne, after a series of trials, whose object was to give the ditches such dimensions that they shoul furnish the earth required for the embankments, regulated the command of the different works as follows. The lowest work, which is the demi-lune covered way, he lays down as a rule, shall command the exterior ground by not less than 7½ feet; and the works most advanced shall be com anded by those in their rear.

33. It was found that, for the purpose of equalizin the excavations and embankments of the front, the crest of the demi-lune covered way should have a command o 10½ feet above the natural ground. The crest of the bastion covered way, and of the re-entering place of arms com- mand the crest of the demi-lune covered way by 2 feet. The magistral of the enceinte is horizontal, its elevation be the same as the mean elevation of the crest of the bastion covered way. The salient of the bastion commands its covered way by 8 feet. The total height of the scarp is 30 feet. This dimension has since been generally adopted by engineers, a wall of this height opposing a sufficient obstacle to an attempt at escalade. The absolute relief of the flanks is thus made 37½ feet; with this relief a piec firing under a depression of ⅛ through an embrasure in th flank, and in the direction of the curtain, will strike th

bottom of the ditch at the middle point of the curtain; so that were the relief increased, the length of curtain remaining the same, the ditch would no longer be thoroughly flanked.

34. The relief of the tenaille is determined as in Vauban's system; so as not to mask the fire of the flanks upon the ditch opposite the extremity of the demi-lune, as it is here that a breach may be made in the bastion face, through the ditch of the demi-lune.

35. The demi-lune is commanded by the enceinte 3 feet, and by its own redoubt 1½ feet; the demi-lune therefore commands its covered way 7 feet, which is more than is indispensably requisite; for, an enemy standing on the crest of the covered way cannot have a plunging fire into a work in the rear of it, if the latter commands the crest by 5 feet.

36. The redoubt of the re entering place of arms commands the crest of the glacis only 4½ feet; its interior crest is so placed as not to mask the fire of the bastion faces on the glacis in advance of it.

37. The interior crests of all the works are 7½ feet above their terre pleins; except that of the tenaille, which is 6½ feet; and of the redoubt of the re entering place of arms which is 9 feet. The interior crests of the faces of all the works exposed to enfilading fires are one foot higher at the

salients than at the extremities.

38. The profile of the parapet of the principal out-works is the same as that of the enceinte.

39. The communications are generally of the same nature, and placed about in the same positions, as in Vauban's system. The planes of the glacis are so determined that they may be swept by the fire of the works in the rear; their inclination is usually about twenty four base to one altitude.

40. From the preceding description, it appears, that the most important modifications made by Cormontaingne in Vauban's first system, consist in the means taken to cover the masonry from distant batteries; an enlarged demi-lune, which places the bastions in strong re enterings, covers the shoulder angles, and admits of a redoubt in its interior, which work strengthens the demi-lune, and sees in reverse the breach made in the bastion face; an enlarged re entering place of arms, containing a redoubt which strengthens the entire covered way, and covers the movement of the troops in sorties.

41. These modifications, although of great value, and constituting an important step in the art, still, leave much to be desired; and engineers since Cormontaingne's time have sought to remedy the defects of his system, of which the following are the principal. The enceinte has

rather too slight a command, and is without any bomb-proof shelters; the inclination of the superior slope of its parapet, which is 1/9, is too small to have the ditches well flanked; a breach can be made in the bastion face through the ditch of the demi-lune; there are dead spaces in the ditch of the demi-lune, near the extremities of its faces; the redoubt of the re entering place of arms is not tenable after the demi-lune is taken; the traverses of the covered way do not afford the requisite protection to that work; finally, the communications are mostly inconvenient, and not well covered from the enemy's fires.

Description and Analysis of the Bastioned Front applied to a Horizontal Site.

42 **General Principles.** Whatever diversity of opinion may be found amongst engineers and writers on permanent fortification, as to the best mode of combining its elements for the attainment of the object in view, most are of accord upon certain conditions as requisites in all combinations; and these points, thus generally admitted, constitute the basis, or general principles by which the practice of the Art is regulated. Of these the following are the most essential.

1st The enceinte should be secure from a surprise by escalade; present an unbroken line, on every side by which it can be approached by an enemy; and have its scarp wall completely swept by the fire of the enceinte.

2nd The masonry of the enceinte and out-works should be masked from all positions that the enemy may take up for his batteries, until he reaches the crest of the covered way; and the parapets of all works be shot proof.

3d As far as the position to be enclosed will admit of it, the faces of the enceinte should be so placed that the enemy will not be able to bring an enfilading fire to bear upon their terre-pleins.

4th The out-works should be so combined as to force the enemy to carry them in succession; with this view they must all be commanded by the enceinte; and those in advance be commanded by the ones more retired; and all be flanked by the musketry of the enceinte. The principal out-works should also be secure from a sudden open assault

5th The communications should be sufficiently spacious to allow a prompt circulation of the troops for sorties and all other services.

43. General Profile, and Plan of the Enceinte.

It is generally admitted by engineers that, for security against an attack by escalade, the scarp wall of the enceinte should be at least 30 feet high. This limit is sanctioned by the example

of Vauban and Cormontaingne, and the experience of sieges.

To escalade a wall of this height would require scaling ladders upwards of 40 feet in length, and strong enough to bear the weight of six or eight men mounting together. To carry forward ladders of this size, and raise them against the wall, with that promptitude requisite to the success of an open assault, would of itself, supposing no other obstacle interposed, be an operation of considerable difficulty; but when it is considered that this must be done under the fire of the assailed, and that a wide and deep ditch has to be crossed under this fire before the foot of the wall can be gained, it is difficult to see how such an undertaking can succeed, if the assailed display the slightest resistance.

44. An unbroken line, that is one presenting no openings through which an enemy might make his way into the interior of the work, is as requisite as a high scarp wall to secure the enceinte from a surprise.

45. To have the scarp wall thoroughly swept by the fire of the enceinte there should be no point along its foot where an enemy could find shelter from this fire. This will require such a combination of the relief and plan of the enceinte as shall afford a perfect flanking arrangement of all the parts.

46. The relief of a work is the height of the

scarp wall added to that of the interior crest of the parapet above the wall. Adopting 30 feet as the least height of scarp wall, the relief will vary only with the height given to the parapet. The least height that the latter can receive will therefore fix the least relief. To ascertain this element, in the case of a parapet formed of ordinary soil and with the usual form and dimensions it will be necessary to find how far above the top of the wall the mouth of an embrasure can be placed so that the line of artillery fire, receiving its greatest inclination of 1/6, shall just touch the exterior edge of the coping. This point can be readily found either by construction, or calculation. To show this, let (Fig. 1. Pl. II.) be the profile of the scarp and parapet; in which the berm is 2 feet; the exterior slope of the parapet 45° or 1/1; the superior slope 1/6; the thickness of the parapet 18 feet, being the least adopted for the enceinte.

Drawing a horizontal line ab through the edge of the coping, a line ac, making an angle 1/6 with ab, will be the direction of the line of artillery fire, passing through a. A line drawn parallel to this last line, and 3 feet above it, will be the direction of the superior slope. A line drawn through e, the foot of the exterior slope, and making an angle 1/1 with ab, will be the position of the exterior slope; and the point m, where

this cuts the superior slope, will be the exterior crest. Setting off from this point the thickness of the parapet, 18 feet, and erecting a perpendicular to ab, the point n, where this perpendicular cuts the superior slope, will be the position of the interior crest, that will satisfy the conditions imposed.

To find this point by calculation, denote by x the base ed = dm of the exterior slope; the berm e = 2 feet; db = 18 feet. Now as the point m is 3 feet below the point n, it follows that the point c, where the line of artillery fire cuts the perpendicular through n, is also 3 feet below this point, and therefore bc = dm = ed = x. Then ab = 6bc, gives $x + 20' = 6x$; and $x = 4'$. Hence bn = $x + 3' = 7'$, which is the least height of n above a, to satisfy the conditions imposed. To avoid all danger to the wall from the artillery fire, this height is usually increased one foot.

From the elements thus determined it follows that 38 feet is the least relief that the enceinte should receive.

47. The bastioned form of enceinte is the only one in which a fire can be brought to bear upon every point of the scarp without introducing other defects of a grave character; and in it the flanking arrangements can be obtained in a thorough manner only by a suitable com-

bination of the relief and the lengths of the lines to be flanked.

48. As the flanks of the bastion are the only lines from which the foot of the scarp wall can be seen, they must be placed so far apart that the foot of the wall of each half front may be under the protection of the fire of the flank opposite to it. For the attainment of this object, the line of artillery fire of each flank, drawn under the greatest angle of depression 1/6, must not pass higher than 1,5 ft above the foot of the scarp at the middle of the curtain. This will bring the musketry fire to bear 9 1/2 feet above the same point.

(If a section be made through the flank along the foot of the curtain wall, Pl. II. Fig. 2.) the horizontal distance of the interior crest of each flank from the middle point of the curtain, to satisfy the foregoing condition can be found by a very simple calculation. For, representing by h the relief of the flank in feet, this distance will evidently be $6 (h - 4.50)$. Taking $h = 38$ ft the corresponding distance along the curtain will be 201 feet, or 67 yards; and the least distance therefore that the interior crests can be placed apart to admit a thorough flanking arrangement will be 134 yards.

As the magistral is the directing line, adopted by engineers in setting out permanent works

it will be requisite to subtract, from the distance 134 yards, twice that between the interior crest and the magistral of each flank, to obtain the length of the magistral of the curtain. But the distance between the interior crest and the magistral is equal to the sum of the thukness of the parapet, 10 feet, the base of the exterior slope, 5 feet, and the distance from the foot of the exterior slope to the magistral which is taken at a foot and a half, the distance to be subtracted from 134 yards will be 2/18+5+1,5) = 49 feet or 16,33 yards. The magistral of the curtain will therefore be equal to $134^{yds} - 16,33^{yds} + = 117,66$ yards. This is consequently the least length of curtain that can be given to a front in which the flanking arrangements are to be thoroughly preserved.

49. In order that every point of the enceinte ditch may be guarded effectively, not only must the distance between the flanks not be less than that just determined, but the position of each flank, with respect to the curtain and face, its length, and that of its line of defence must be so combined that all points on which the enemy can establish himself to fire upon the ditch shall be within the effective range of the arm used for flanking the enceinte.

From the exposed position of the artillery of the assailed, and the destructive fire of the enemy, it

would be extremely hazardous to the safety of a work to base its flanking arrangements solely upon artillery. On the other hand, were the range of the musket assumed as the basis of these dispositions, the lines of defence could not exceed 180 yards, and this would lead to small fronts, which, to enclose a given position, would increase the number of salients, or weak points, require a greater development of masonry, with an increase of cost over larger fronts, and farther, in circumstances where it would be desirable to place outworks, an efficient flanking arrangement could not be procured for them from the enceinte, without so reducing the dimensions suitable to these works as greatly to impair their efficiency.

50. These and other considerations have led engineers to base the flanking arrangements of the enceinte on the "Wall-piece, or Rampart-gun of which the effective range is between 350 and 400 yards. To bring under the fire of this arm, the besiegers works, on the glacis in front of the bastion salient, which, allowing for the width of the ditch and Covered-way, are within 50 yards of the salient, the line of defence should not exceed 300 yards, and this distance may therefore be taken as its greatest limit.

51. The position of the flank with respect to the curtain and the opposite face has been variously chosen

between a perpendicular to the curtain, at the point where it cuts the line of defence, and a perpendicular to the opposite face, or line of defence from the same point. The position perpendicular to the curtain is unfavorable to sweeping the face by the same embrasure from which the curtain can be sweept. The one perpendicular to the line of defence is less objectionable, so far as the flanking of the curtain is concerned, still it is less favorable, under some other points, than a position intermediate to these two; and engineers have, in most cases, adopted the latter; so placing the flank as to make an angle of 100° with the curtain, the position nearly given to it in Vauban's system. Between this last position and that perpendicular of the line of defence, there is the advantage in favor of the former, that, when the length of the curtain is fixed, it gives a longer face than the latter, which in fronts with out works, may be desirable, for the better flanking arrangements of these works.

52. To guard the enceinte from surprise by escalade, the flank should be of sufficient length to carry at least two guns, which shall sweep both the curtain and face. It is usually estimated that a length of 18 yards will be sufficient for this purpose, this is therefore the least length of flank allowed.

53. The flank may be increased beyond this limit

to any extent demanded by the circumstances of the defence. It must however be observed that, as the line of defence cannot exceed 300 yards, its greatest limit, the flank, from the position assigned it above, can only be increased by lengthening the curtain, and that thus the interior space within the bastion will be diminished, and the two flanks of the bastion be brought nearer together. In very acute bastions therefore the interior space and the gorge might become so contracted, by an undue length of flank, as not to admit of suitable arrangements for an efficient defence and circulation. These and other considerations have led engineers to restrict the flank to certain limits; adopting as a general rule that the flank shall be of sufficient length to carry at least as many guns as the enemy can place in battery against it, along the glacis of the covered way in front of the bastion salient. The length of this line occupied by the enemy's battery will depend on the plan or trace of the enceinte and its ditch. The flanks in Vauban's system are found to vary between 50 and 55 yards; in Cormontaingnes they are between 40 and 48 yards. Following these authorities, and taking into consideration the reasons already stated for restricting the length of the flank, 50 yards may be taken as the greatest length of flank.

54 The face of the bastion is usually directed on the

curtain angle. In this position, the entire fire of the flank can be brought to bear on the enceinte ditch, along the foot of the face scarp wall. Circumstances may require a different position than this for the face; directing it either on some point of the curtain between the extremities; or on some point of the flank between the curtain and shoulder angles. When directed on a point of the curtain between its extremities, the opposite flank will have a better reverse view on the face than when the usual position is given to the face; but the salient angle of the bastion will, at the same time, be made more acute. When directed on a point of the flank between the curtain and shoulder angle, a part of the fire of the opposite flank will not be brought to bear on the foot of the scarp wall of the face; but the salient of the bastion will be larger than that obtained by the usual position of the face.

55. The length of the face will evidently depend upon the dimensions of the curtain, the flank, and the line of defence, with the relative positions of these lines. By reducing the line of defence to the distance between the curtain angle and its opposite shoulder angle, the face would be reduced to zero, and the front consist only of the curtain and its two flanks. By giving the line of defence its greatest length, (Pl. II. Fig. 3.) and reducing the curtain and

flanks to their least dimensions, a very simple construction will show that the resulting face will be the greatest attainable. The same construction will show that the exterior side resulting from this combination of elements will be also the greatest.

56. From the foregoing examinations the following rules for regulating the relief and plan of the enceinte are deduced.

1st. The scarp wall should not be less than 30 feet high, nor the interior crest of the parapet less than 8 feet above the magistral of the scarp; thus giving 38 feet as the least height between the top of the parapet and foot of the wall, or the least relief.

2d. The curtain must be of sufficient length to be swept throughout by the flank fire. The shortest curtain, in which this condition can be satisfied, and which corresponds to the least relief, being 117.66 yards, estimated along the magistral.

3d. The flanks, as a general rule, should make an angle of 100° with the curtain. The least length of flank should be 18 yds, and the greatest length 60 yds.

4th. The line of defence should not exceed 300 yds.

5th. The direction of the face, as a general rule, should pass through the curtain angle. The least length of face is zero, and its greatest length will result from combining the least curtain, least flank, and greatest line of defence.

6th. The exterior side will result from the combination of the foregoing elements. The least exterior side resulting from combining the least curtain, least flank and least face; the greatest exterior side, from the least curtain, least flank and greatest line of defence.

57. The preceding deductions result from the supposition that the enceinte ditch is dry. When a depth of 6 feet of water can be constantly maintained in this ditch, it alone is considered as a strong safeguard against a surprise by escalade; and engineers are generally agreed that a scarp wall of 24 feet is a sufficient security in this case, even in northern climates where an attempt at surprise might be made by crossing the enceinte ditch on the ice; as by care taken in keeping a channel open in the middle of the ditch, and piling up the ice, daily taken from it, along the borders of this channel, an additional obstacle would be thrown in the way of the enemy

As in a wet ditch it will be only necessary to bring the fire of the flank to bear on the surface of the water at the middle of the curtain, to ensure a through flanking arrangement; it is obvious that the least length of curtain will be less than that obtained for a dry ditch.

58. In the various combinations of which the elements of the bastion system, taken within their extreme limits, are susceptible, it will at once be seen that the size of the

resulting bastions must also vary greatly. The engineer, in selecting from among these combinations, must take as his main guide, in determining upon each case presented for his consideration, all the circumstances connected with its defence.

On fronts requiring no other outworks than the covered way, long curtains and, consequently, small bastions will be most suitable; particularly if the bastion faces are exposed to the enemy's enfilading fire, as the curtain, from its position, is mostly secure from this fire, and, where no outworks interpose, its fire sweeps effectually the ground in advance of it. Where out works are requisite, the curtain must be restricted, in most cases, to its least length, in order to obtain long faces for the bastion, and a strong column of fire to flank the out-works.

59. In regulating the dimensions of the parts of the bastion system, engineers have commonly adopted the general method of Vauban and Cormontaingne, which is to assume the exterior side and the relief of the encente, and to determine the other parts from these two elements. There is nothing which obliges to this particular method, but it seems the most natural, since, in enclosing a given space with a line of fortification, the salient points would, in general, be first attended to, as the weakest; and the exterior sides are a consequence.

of the positions selected for these points. Vauban and Cormontaingne also, except when the loiality demanded a different course, made the dimensions of the corresponding parts of each front the same and placed them symmetrically with respect to the perpendicular of the front.

In the following constructions, which are to be regarded in no other light than as a particular problem of permanent fortification, to illustrate the application of general principles, and particular methods employed in all other cases, we shall follow the method of these two engineers; a course that has been generally adopted by others.

60 Exterior Side, Relief and Command of the Front. Let us take the exterior side of a bastion enceinte, to be laid out on a horizontal site, 380 yds. The height of its scarp wall 33 feet. The height of the interior crest of the curtain above its magistral 13 feet which is also the same as that of the point where it joins the flank. The relief of this last point above the foot of the scarp at the middle point of the curtain 44.50 feet; and its command over the plane of site 21 feet.

61. Profile of Enceinte. Pl. II. Fig. 4. Let the following slopes and dimensions be taken for those parts of the profile which are invariable. The scarp and counterscarp slopes 24/1, or one base to twenty-four altitude. Exterior slope 1/1, or 45°. Superior slope 1/6. Interior slope 3/1.

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48. As the flanks of the bastion are the only lines from which the foot of the scarp wall can be seen, they must be placed so far apart that the foot of the wall of each half front may be under the protection of the fire of the flank opposite to it. For the attainment of this object, the line of artillery fire of each flank, drawn under the greatest angle of depression 1/6, must not pass higher than 1,5 feet above the foot of the scarp at the middle of the curtain. This will bring the musketry fire to bear 4 1/2 feet above the same point.

If a section be made through the flank along the foot of the curtain wall, (Pl. II. Fig. 2.) the horizontal distance of the interior crest of each flank from the middle point of the curtain, to satisfy the foregoing conditions can be found by a very simple calculation. For, representing by h the relief of the flank in feet, this distance will evidently be $6(h - 4.50)$ ft. Taking h = 38 feet the corresponding distance along the curtain will be 201 feet, or 67 yards; and the least distance therefore that the interior crests can be placed apart to admit a thorough flanking arrangement will be 134 yards.

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of the positions selected for these points. Vauban and Cormontaingne also, except when the loiality demanded a different course, made the dimensions of the corresponding parts of each front the same and placed them symmetrically with respect to the perpendicular of the front.

In the following constructions, which are to be regarded in no other light than as a particular problem of permanent fortification, to illustrate the application of general principles, and particular methods employed in all other cases, we shall follow the method of these two engineers; a course that has been generally adopted by others.

60 Exterior Side, Relief and Command of the Front. Let us take the exterior side of a bastion enceinte, to be laid out on a horizontal site, 380 yds. The height of its scarp wall 33 feet. The height of the interior crest of the curtain above its magistral 13 feet which is also the same as that of the point where it joins the flank. The relief of this last point above the foot of the scarp at the middle point of the curtain 44.50 feet; and its command over the plane of site 21 feet.

61. Profile of Enceinte. Pl. II. Fig. 4. Let the following slopes and dimensions be taken for those parts of the profile which are invariable. The scarp and counterscarp slopes 24/1, or one base to twenty-four altitude. Exterior slope 1/1, or 45°. Superior slope 1/6. Interior slope 3/1.

Banquette slope ½. Rampart slope ⅔. Terre-pleins 8 feet below the interior crests. Berm 2 feet. Distance between the magistral and foot of the exterior slope 1.5 ft. Thickness of parapet 20 ft Height of interior crest above banquette tread 4.5 feet. Banquette tread 4.5 ft. General width of terre-plein estimated from the vertical through the interior crest 48 feet.

62. Magistral of Curtain. Before proceeding to make the drawing of the plan of the enceinte, for which we shall adopt the scale of one inch to fifty feet, and the plane of comparison 60 feet below the plane of site; we shall first, by calculations, like those in (Art. 48), determine the least curtain measured on the magistral, corresponding to the given relief, 44.50 ft., of the lowest point of the flank above the middle of the foot of the curtain scarp wall. This will be equal to the horizontal distance between the interior crest of the flanks, which is $12(44,50 - 4,50) = 480$ feet, diminished by twice the horizontal distance between the interior crests and the magistral, which is $2(20 + 9,66 + 15) = 62,33$ feet, or $480 - 62,33 = 417.66$ feet $= 139,22$ yards.

63. Magistral of Enceinte Pl. II. Fig 5. Having found the length of the magistral of the curtain, the projection of the magistral of the enceinte on the plane of reference is determined as follows. Draw a line for the

exterior side, and set off on it AB = 380 yards; bisect this distance by a perpendicular, on which set off CD = 1/6 AB = = 63,33 yds; from A and B draw lines through D, these are the directions of the faces and lines of defence; draw a parallel to CD on each side of it, and at 69,61 yds, the lengt of the half curtain. from it, join the points G and H where these parallels intersect the lines AD and BD prolonged; GH is the position of the curtain; GB and HA the lines of defence; from G and H draw a line making an angle 1/6 with the perpendicular to the curtain at each of these point the parts GE and FH of these last lines are the flanks; and AE and BF the faces.

64 The position of the magistral with respect to the plane of reference is determined as follows. The magistral of the curtain is horizontal. As it is 13 feet below the interior crest, and this line is placed at 21 feet above the plane of site, the magistral is 8 feet above this plane, and therefore, from the position given the plane of comparison, 68 feet above this last plane; its reference therefore is (68,0). The flank is 1.5 lower at the shoulder than at the curtain angle, the reference of the shoulder is then (66,50). The face is horizontal, and its reference also (66,50)

65. Manner of determining the position of a point of the Interior Crest. To determine the projection of a point of the interior crest contained in a profile

[illegible] the crest of the rivet above the magistral being known [illegible] subtract from this height ½ the thickness of the parap[illegible] the remainder will be the height of the exterior crest [illegible] the magistral. and, when the exterior slope is ½, will [illegible] the base of the slope, adding together the thickness [illegible] the crest. the base of the exterior slope as just determin[illegible] and the distance from the foot of the exterior slope to the magistral. the sum will be the horizontal distance between the magistral and interior crest, or the distance to be set off. along the trace of the profile plane, from the magistral. to obtain the projection of the required point of the interior crest.

Interior Crest of the Enceinte. Pl. II. Fig. 6.

The position of the interior crest above the magistral is fixed as follows. That of the curtain is parallel to the magistral and 3 feet above it. Those of the flanks and faces of the bastion are contained in the same plane, the scale of slopes of which is taken parallel to the bastion capital. The position of this plane is determined by placing its horizontal, which coincides with a pan-coupé 4,30 yds in length at the bastion salient, at 4,60 above the horizontal drawn through the points where the flanks join the curtain.

The reference of the interior crest of the curtain from the above data will therefore be (81,0) and the

8.00 -
+20. + 1.5) = 31.16

horizontal distance of any point of it from the magistral 31,16 ft. or 10,38 yds as these two lines are parallel.

Having drawn the projection of the interior crest of the curtain, the point where it joins the flank may be determined approximately, and with sufficient accuracy, by bisecting the curtain angle of the magistrals, and taking the point, where the bisecting line cuts the interior crest, as the extremity of the flank. From this point, of which the reference is (81, 0), if a line be drawn perpendicular to the bastion capital it will be the horizontal (81, 0) of the plane of the interior crests of the bastion; that at the pan-coupé is $4,^{ft}50$ higher, and its reference will therefore be (85, 50).

To find the position of this last horizontal, which is also that of the pan-coupé, draw two lines parallel to the bastion capital and 2,15 yds from it, they will limit the pan-coupé. Now, as the extremity of the pan-coupé is a point of the interior crest of the bastion face, and its reference is (85, 50), the height of this point above the magistral is 19 ft, as the reference of this last line is (66, 50). The horizontal distance therefore from this point to the magistral is $(20^{ft} + 15,^{ft}66 + 1,^{ft}50) - 37,^{ft}16 = 12,38$ yds. Drawing a parallel therefore to the magistral of the face and at 12,38 yds from it, the point where it cuts the parallel to the capital, at 2,15 yds from

it, will be the required point, through which the horizontal (85, 50) is drawn.

Having two horizontals of the plane, its scale of declivity can be constructed, and other horizontals be determined. The projection of the point of the interior crest of the face on any given horizontal can be found by the same process as the one just described. For example take the horizontal (84, 0); the perpendicular distance of the point on it from the magistral is $(\overset{ft.}{20} + \overset{ft.}{14},16 + \overset{ft.}{1},\overset{ft.}{50}) = \overset{ft.}{35},\overset{ft.}{66}$ or 11.88 yds. The two points thus determined being joined will give the projection of the interior crest of the face.

To find that of the flank, of which one point (81, 0) has been found, bisect the shoulder angle of the magistral, the point where the bisecting line cuts the interior crest of the face will give approximately the other extremity of the line required.

The constructions for the interior crests, just given, are only approximations to a true result; as the horizontal distances calculated, being those contained in profile planes, ought to have been set off perpendicular to the projection of the interior crest: but the difference between the results of this approximate method and one rigorously accurate will, in the present case, be so small, owing to the slight divergence between the projections of the magistral and interior crest of the face, as not to affect, in any

appreciable degree, the real positions of the required points. The same remarks are applicable to the constructions for finding the extremities of the flank

67. **Parapet of Enceinte.** Having drawn the interior crest of the enceinte, all the other lines of the parapet, (except the foot of the exterior slope), and the inward line of the terre-plein are drawn parallel to it. The foot of the exterior slope is drawn parallel to the magistral.

68. **Terre plein of Enceinte Pl. II. Fig. 6.** The terre-pleins of the faces and flanks are in a plane parallel to that of their interior crest and 8 feet below it estimated vertically. To find the reference of any horizontal of the terre-plein, it will be only necessary to subtract 8 feet from the corresponding one of the interior crests. Thus (85, 50) being the reference of a horizontal of the interior crest, that of the terre plein corresponding is (77, 50).

The terre-plein of the curtain slopes 1 ft from the foot of the banquette slope to its inward line, which places this last line 9 ft below the interior crest.

$\frac{1}{35}$ Slope

69. **Rampart-Slope and Ramps. Pl. II. Fig. 6.** The rampart slopes are planes of 2/3 passed through the inward lines of the terre-pleins. The lines of intersection of the rampart slopes and plane of site are found in the usual way. (Prob. 19. Fig. 24).

70. **Ramps.** The ramps leading from the plane of site to the terre-plein receive an inclination of 1/9, and they are 4.30 yds. wide. Two of them are placed on the curtain; one on the flank; and one on the face.

To construct each ramp we select its point of departure on the foot of the rampart slope; from this point we draw a line of 1/9 on the rampart-slope which is the inner line of the ramp, its outer edge being parallel to this line and 4,30 yds from it. The horizontals of the ramp are taken perpendicular to the two last lines. From these data the intersections of the plane of site and terre-plein with the ramp can be readily found (Prob. 19. Fig 24) by the usual construction for finding the intersection of two planes having their horizontals given. These intersections will give the foot and top of the ramp.

71. **Barbette. Pl. I. Fig. 7.** A barbette for five pieces is placed in the salient of the bastion. The top of the barbette is horizontal and 2.75 ft below the int. crest at the pan-coupé, its reference therefore is (82,75). It is bounded, by setting off 8 yds along the capital, from the foot of the pan-coupé, and from this point drawing a perpendicular to the interior crest of each face; these perpendiculars limit the space occupied by the piece in the direction of the capital. From the extremities of these perpendiculars, distances of 12 yds are sett off along the

interior crests; and perpendiculars of 3 yds set off, from these last points, to the interior crests; and the inward lines of the barbette are drawn through the extremities of these last perpendiculars and parallel to the interior crests. The embankment of the barbette is finished by slopes of 1/1; the intersections of which with the terre plein are found in the usual way.

Two ramps of 1/6 and 3,30 yds wide, lead from the plane of site to the barbette. The interior line of each ramp is projected in the same line as the foot of the banquette slope. The ramps are terminated on the sides by planes of 1/1. The foot of the ramp and the intersections of its side slopes with the terre-plein and banquette slope are found (Prob. 19. Fig. 24.) in the usual way.

72. **Analysis of Constructions adopted for the Enceinte.** The dimensions and form of the profile are those usually adopted for permanent works, where the embankments are formed of ordinary earth, and the revetment walls are of good masonry.

They are such as experience has shown will give durability and stability to the masonry, from the pressure of the embankments, and the ordinary causes of destructibility to which it is liable when exposed to the weather; and to the rampart and parapet the strength to resist the action of the heaviest artillery, whilst they offer to the as-

resulting bastions must also vary greatly. The engineer, in selecting from among these combinations, must take as his main guide, in determining upon each case presented for his consideration, all the circumstances connected with its defence.

On fronts requiring no other outworks than the covered way, long curtains and, consequently, small bastions will be most suitable; particularly if the bastion faces are exposed to the enemy's enfilading fire, as the curtain, from its position, is mostly secure from this fire, and, where no outworks interpose, its fire sweeps effectually the ground in advance of it. Where out works are requisite, the curtain must be restricted, in most cases, to its least length; in order to obtain long faces for the bastion, and a strong column of fire to flank the out-works.

59. In regulating the dimensions of the parts of the bastion system, engineers have commonly adopted the general method of Vauban and Cormontaingne, which is to assume the exterior side and the relief of the enceinte, and to determine the other parts from these two elements. There is nothing which obliges to this particular method, but it seems the most natural, since, in enclosing a given space with a line of fortification, the salient points would, in general, be first attended to, as the weakest; and the exterior sides are a consequence

of the positions selected for these points. Vauban and Cormontaingne also, except when the loiality demanded a different course, made the dimensions of the corresponding parts of each front the same and placed them symmetrically with respect to the perpendicular of the front.

In the following constructions, which are to be regarded in no other light than as a particular problem of permanent fortification, to illustrate the application of general principles, and particular methods employed in all other cases, we shall follow the method of these two engineers; a course that has been generally adopted by others.

60 Exterior Side, Relief and Command of the Front. Let us take the exterior side of a bastion enceinte, to be laid out on a horizontal site, 360 yds. The height of its scarp wall 33 feet. The height of the interior crest of the curtain above its magistral 13 feet which is also the same as that of the point where it joins the flank. The relief of this last point above the foot of the scarp at the middle point of the curtain 44.50 feet; and its command over the plane of site 21 feet.

61. Profile of Enceinte. Pl. II. Fig. 4. Let the following slopes and dimensions be taken for those parts of the profile which are invariable. The scarp and counterscarp slopes 24/1, or one base to twenty four altitude. Exterior slope 1/1, or 45°. Superior slope 1/6. Interior slope 3/1.

Banquette slope ½. Rampart slope 2/3. Terre-pleins 8 feet below the interior crests. Berm 2 feet. Distance between the magistral and foot of the exterior slope 15 ft. Thickness of parapet 20 ft. Height of interior crest above banquette tread 4.5 feet. Banquette tread 4.5 ft. General width of terre-plein estimated from the vertical through the interior crest 48 feet.

62. Magistral of Curtain. Before proceeding to make the drawing of the plan of the enceinte, for which we shall adopt the scale of one inch to fifty feet, and the plane of comparison 60 feet below the plane of site; we shall first, by calculations, like those in (Art. 48), determine the least curtain measured on the magistral, corresponding to the given relief, 44.50 ft., of the lowest point of the flank above the middle of the foot of the curtain scarp wall. This will be equal to the horizontal distance between the interior crest of the flanks, which is $12(44^{ft.},50 - 4^{ft.},50) = 480$ feet, diminished by twice the horizontal distance between the interior crests and the magistral, which is $2(20^{ft.} + 9^{ft.},66 + 15^{ft.}) = 62^{ft.},33$ feet, or $480^{ft.} - 62^{ft.},33 = 417.66$ feet $= 139^{yds.},22$ yards.

63. Magistral of Enceinte Pl. II. Fig 5. Having found the length of the magistral of the curtain, the projection of the magistral of the enceinte on the plane of reference is determined as follows. Draw a line for the

exterior side, and set off on it AB = 380 yards; bisect this distance by a perpendicular, on which set off CD = 1/6 AB = = 63,33 yds; from A and B draw lines through D, these are the directions of the faces and lines of defence; draw a parallel to CD on each side of it, and at 69,61 yds, the length of the half curtain, from it, join the points G and H where these parallels intersect the lines AD and BD prolonged; GH is the position of the curtain; GB and HA the lines of defence; from G and H draw a line making an angle 1/6 with the perpendicular to the curtain at each of these points, the parts GE and FH of these last lines are the flanks, and AE and BF the faces.

64 The position of the magistral with respect to the plane of reference is determined as follows. The magistral of the curtain is horizontal. As it is 13 feet below the interior crest, and this line is placed at 21 feet above the plane of site, the magistral is 8 feet above this plane, and therefore, from the position given the plane of comparison, 68 feet above this last plane; its reference therefore is (68,0). The flank is 1.5 lower at the shoulder than at the curtain angle, the reference of the shoulder is then (66,50). The face is horizontal, and its reference also (66,50)

65. Manner of determining the position of a point of the Interior Crest. To determine the projection of a point of the interior crest contained in a profile

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horizontal distance of any point of it from the magistral 31,16 ft. or 10,38 yds as these two lines are parallel.

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Having drawn the projection of the interior crest of the curtain, the point where it joins the flank may be determined approximately, and with sufficient accuracy, by bisecting the curtain angle of the magistrals, and taking the point, where the bisecting line cuts the interior crest, as the extremity of the flank. From this point, of which the reference is (81,0), if a line be drawn perpendicular to the bastion capital it will be the horizontal (81,0) of the plane of the interior crests of the bastion; that at the pan-coupe' is 4,$^{ft}_{50}$ higher, and its reference will therefore be (85,50).

To find the position of this last horizontal, which is also that of the pan-coupé, draw two lines parallel to the bastion capital and 2,15 yds from it, they will limit the pan-coupe'. Now, as the extremity of the pan-coupe' is a point of the interior crest of the bastion face, and its reference is (85,50), the height of this point above the magistral is 19 ft, as the reference of this last line is (66,50). The horizontal distance therefore from this point to the magistral is ($^{ft}_{20}$ + $^{ft}_{15,66}$ + $^{ft}_{1,50}$) - $^{ft}_{37,16}$ = 12,38 yds. Drawing a parallel therefore to the magistral of the face and at 12,38 yds from it, the point where it cuts the parallel to the capital, at 2,15 yds from

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67. **Parapet of Enceinte.** Having drawn the interior crest of the enceinte, all the other lines of the parapet, (except the foot of the exterior slope), and the inward line of the terre-plein are drawn parallel to it. The foot of the exterior slope is drawn parallel to the magistral.

68. **Terre plein of Enceinte Pl. II. Fig. 6.** The terre-pleins of the faces and flanks are in a plane parallel to that of their interior crest and 8 feet below it estimated vertically. To find the reference of any horizontal of the terre-plein, it will be only necessary to subtract 8 feet from the corresponding one of the interior crests. Thus (85, 50) being the reference of a horizontal of the interior crest, that of the terre plein corresponding is (77, 50).

The terre-plein of the curtain slopes 1 ft from the foot of the banquette slope to its inward line, which places this last line 9 ft below the interior crest.

$\frac{1}{35}$ Slope

69 **Rampart-Slope and Ramps. Pl. II. Fig. 6.** The rampart slopes are planes of 2/3 passed through the inward lines of the terre-pleins. The lines of intersection of the rampart slopes and plane of site are found in the usual way. (Prob. 19. Fig. 24).

70. **Ramps.** The ramps leading from the plane of site to the terre-plein receive an inclination of 1/9, and they are 4.30 yds. wide. Two of them are placed on the curtain; one on the flank; and one on the face.

To construct each ramp we select its point of departure on the foot of the rampart slope; from this point we draw a line of 1/9 on the rampart-slope which is the inner line of the ramp, its outer edge being parallel to this line and 4,30 yds from it. The horizontals of the ramp are taken perpendicular to the two last lines. From these data the intersections of the plane of site and terre-plein with the ramp can be readily found (Prob. 19. Fig 24) by the usual construction for finding the intersection of two planes having their horizontals given. These intersections will give the foot and top of the ramp.

71. **Barbette. Pl. I. Fig. 7.** A barbette for field pieces is placed in the salient of the bastion. The top of the barbette is horizontal and 2.75 ft below the interior crest at the pan-coupé, its reference therefore is (82,75). It is bounded, by setting off 8 yds along the capital, from the foot of the pan-coupé, and from this point drawing a perpendicular to the interior crest of each face; these perpendiculars limit the space occupied by the piece in the direction of the capital. From the extremities of these perpendiculars, distances of 12 yds are sett off along the

interior crests; and perpendiculars of 3 yds set off, from these last points, to the interior crests; and the inward lines of the barbette are drawn through the extremities of these last perpendiculars and parallel to the interior crests. The embankment of the barbette is finished by slopes of 1/1; the intersections of which with the terre plein are found in the usual way.

Two ramps of 1/6 and 3,30 yds wide, lead from the plane of site to the barbette. The interior line of each ramp is projected in the same line as the foot of the banquette slope. The ramps are terminated on the sides by planes of 1/1. The foot of the ramp and the intersections of its side slopes with the terre-plein and banquette slope are found (Prob. 19. Fig. 24.) in the usual way.

72. Analysis of Constructions adopted for the Enceinte. The dimensions and form of the profile are those usually adopted for permanent works, where the embankments are formed of ordinary earth, and the revetment walls are of good masonry.

They are such as experience has shown will give durability and stability to the masonry, from the pressure of the embankments, and the ordinary causes of destructibility to which it is liable when exposed to the weather; and to the rampart and parapet the strength to resist the action of the heaviest artillery, whilst they offer to the as-

sailed every convenience for their prompt action, and the use of their arms.

The width and slopes of the ramps are regulated for the passage of artillery. Where the height to be overcome is slight, as that between the terre-plein and barbette, the slope of the ramp may be as great as 1/6, and its width be 3,30 yard. Where the height is greater, the declivity of the ramp should be proportionally less steep, and its width be 4,30 yards at least.

The position of the terre-plein with respect to the interior crests is that usually considered necessary to give shelter to the troops and materiel on it. By inclining that of the bastion, the materiel and personnel on the faces and flanks are better covered from the enfilading and ricochet fire than they would be if the terre-plein was horizontal; as a ball passing over the salient will reach an inclined terre-plein at a point farther from the salient than one which is horizontal. The height 4,50 feet, at which the salient is placed above the curtain, is as great as can be admitted in a hexagon, the least polygon to which the trace adopted is applicable; because, if placed higher, the plane of the interior crest of the bastion, prolonged back, would intersect the plane of site in a line which would fall without the salients of the two adjacent bastions of the polygon, and these bastions

would therefore not cover the one between them from reverse fire.

The slopes moreover of the terre-pleins keep them in a serviceable state, by not allowing the rain-water to collect and remain upon them.

73. Particular Conditions of the Out-works.

The out-works, besides satisfying the general conditions already laid down, are connected with each other by several minor relations of defence and suitableness, growing out of their relative positions, which give rise to many seemingly arbitrary constructions and details for each one, the bearing of which cannot be clearly understood until a description of the whole as a system has been gone into

The scarp walls of out-works, as well as their gorges where they are exposed to be turned, should not be less than 12 ft high to secure them from a sudden open assault.

Their parapets are of the same form as that of the enceinte; and for the more important ones, which are much exposed to the artillery of the assailant, of the same dimensions. In those less exposed, the thickness of the parapet may be reduced to 12 ft, or 4 yds.

The terre-pleins of the smaller out-works, which are not habitually armed with artillery, should not be less than 8 yds; those of the larger should not

be less than 10 yards.

The banquette treads of out-works which, like the caponnières and covered-ways, require a palisading for their greater security from assault, should be 6 ft. wide.

74. Tenaille. Pl. II. Figs. 1. 2. We shall adopt for the tenaille the form given it in Cormontaingné's front; placing the magistral of its curtain parallel to that of the curtain of the enceinte, and the scarp of its wings on the prolongation of the scarp of the bastion faces.

We leave a ditch of 13 yds between the gorge of the tenaille and the enceinte curtain; and one of 11 yds between each of its wings and the flanks. The magistral of its curtain is horizontal, and 13 ft above the crests of the double caponnière. The magistral of each wing is a broken line, the lowest point of it being 13 ft above the bottom of the enceinte ditch. Its gorge and the extremities of its wings are revetted. Its interior crest is horizontal throughout, and 4,50 ft. below the magistral of the enceinte curtain. The thickness of its parapet 12 ft. The width of the terre plein at its curtain 8,66 yards. The parapet is terminated at the wings by traverses 12 ft thick, which extend from the interior crest to the scarp wall of the wings; the top of each traverse is on the same level as the interior crest. The traverses

are terminated towards the parapet by planes of 1/1.

To construct the principal lines of the tenaille from the preceding data, we first draw a line parallel to the enceinte curtain, and 13 yds from it, for the gorge of the tenaille curtain; another line parallel to this, and at 8,66 yds, is the interior crest, of which the reference is (63,50), as it is 4,50 ft below the enceinte magistral at the curtain.

A level passage at 31,50 ft below the magistral of the enceinte curtain and at the ref.(36.50), leads from the main ditch between the enceinte and tenaille, under this last work, and through a double caponnière in the main ditch in advance of it. The crests of the caponnière are 9 feet above the level of the passage and at the ref.(45,50); and the magistral of the tenaille curtain 13 feet above these crests and at the ref.(58,50). The interior crest of the tenaille having the ref.(63,50), is therefore 5 ft. above its magistral. The horizontal distance then between the mag. and int. crest (Art. 65.) is 12 + 3 + 1.5 = 16.5 ft, or 5.50 yds; and as these lines are horizontal their projections will be parallel and at this distance apart.

The int. crest and magistral of the wing will result from the following data. The scarp wall of the wing extends to the top of the traverse ref.(63,50); its magistral then descends, from this level in the plane of 1/1, which terminates this traverse, to a level of 13 ft

above the bottom of the enceinte ditch, which being at this part 3 ft lower than the passage of the double caponnière, and at ref 33.53'. will give (46,50) for the ref. of the lowest point of the mag. of the wing; the ref. of the point where it joins that of the curtain being, as already determined. 53.5.

To find then the lowest point of this magistral, draw a line 12 ft = 4 yds. from the extremity of the wing, for the exterior line of the traverse; parallel to this line draw another at 17 ft = 5.66 yds, which is the base of the slope of the that terminates the traverse, where this line cuts the line of defence is the required point. The horizontal distance between this point and the int crest. calculated in the usual manner is 12 + 16 + 1.50 = 28.50 ft = 9.50 yds.

Describing from the point just found an arc with a radius 9.50 yds, and from the other extremity of the mag another arc with a radius 5,50 yds, and drawing a tangent to these arcs, it will be the int crest of the wings

The proper line of the wing is not drawn parallel to the int crest, but determined as follows. From the point of intersection of the int. crests of the curtain and wings describe an arc with a radius 8,66 yards, from the point where the enceinte curtain magi

ral prolonged cuts the interior crest of the opposite flank, draw a line tangent to this arc, which will be the direction of the required line.

The gorge wall rises to the level of the terre-plein. That which terminates the wing is limited by the planes of the parapet, terre-plein, and top of the traverse, and is termed a profile wall, from the form of its outline.

75. Analysis of Consructions &c. of the Tenaille. The tenaille is more important as a mask than as a defensive work. It covers the postern in the curtain, and also the masonry of the flanks and curtain from the enemy's batteries; which last is an essential point, if there are interior retrenchments resting either on the flanks, or curtain of the enceinte, as it will then be impracticable for an enemy to turn them, as he cannot make a breach in the enceinte behind the tenaille. As a defensive work its fire bears upon the ditches, and their counterscarps, and it thus serves to cover the retreat of the troops from the other outworks. When the ditches are dry, it is an indispensable part of the front, as the space in its rear forms a large place of arms where troops can be assembled to manoeuvre against the enemy when in the ditches.

Vauban, and Cormontaingne, we have seen so fixed the relief of the tenaille as not to mask the fire of the flanks on the breach in the bastion. It is on this principle that we have determined the position of its interior crest, and placed it at 4,50 ft below the mag. of the curtain.

In regulating its scarp wall, we have supposed, that an enemy would attempt an assault from some point in the dead space in front of it; and have therefore arranged its height, so that no part of it shall be less than 13 ft above any point that the enemy might there occupy.

The position given to its int. crest still leaves some portion of the masonry behind it exposed; but were the exposed part battered away, there would be still a formidable height of scarp left to the enceinte, the parapet of which also would be but slightly diminished in thickness by it. The portion of the enceinte flank exposed, near the shoulder angle, would be very considerable, were the exterior slope of the tenaille parapet extended to the extremity of the wing; it is to prevent this that we have placed a traverse here.

The tenaille is seldom armed with cannon, although mortars are frequently placed in it

on this account we have reduced its terre plein to 8,66 yds.

Every part of the ditch between the tenaille and curtain should be swept by the flanks. It is to satisfy this condition that we have drawn the gorge line of the wing so as to be seen by the piece that flanks the curtain of the enceinte.

The tenaille, although procuring decided advantages to the bastioned form, deprives it of one of its characteristic points, that of flanking every part of the ditch. For, in front of the tenaille, there is a dead space, where an enemy could assemble in safety to assault it. This defect, however is of trifling magnitude, since were the tenaille taken, he could not establish himself in it; and the width given to the ditch, between it and the enceinte flank, is such, as to preclude any attempt to escalade the enceinte from the top of the tenaille.

The terre plein of the tenaille is inclined, for the purpose of defiling it from the enemy's establishment on the terre-plein of the demi-lune redoubt. The inclination of the plane of defilement depends on the arrangement of this redoubt.

76 **Double caponniere** Pl. II. Figs. 1. 2. The passage of the double caponnière is 3,30 yds wide at the bottom and on the same level as the bottom of the ditch at the middle of the curtain ref. (36, 50). The int. crests of the

work are at 9 ft. above the bottom of the passage; they are horizontal, and their ref. (45,50). In the profile of the caponnière the base of the int. slope is 0,50 yd; the banquette is 2,0 yds, wide; and the base of the banquette slope 3,0 yds; the horizontal distance then between the int. crest, and the foot of the banquette slope, is 5,50 yds; which being doubled, and added to 3,30 yds, the wiitth of the passage, gives 14,30 yds, for the distance between the int. crests. The crests are drawn parallel to the perpendicular of the front, and limited by the curtain of the tenaille on one side, and a line drawn parallel to, and 3,30 yds, within, the exterior side on the other.

The embankment of the caponnière is terminated on the exterior by a glacis, which is prolonged to the bottom of the ditch. This glacis is determined, by passing a plane through the int. crest of the caponnière, and through the shoulder angle of the int. crest of the opposite bastion lowered 3 feet.

The caponnière is terminated towards the exterior side by a profile wall, along the line at 3,30 yds within the exterior side, this wall is prolonged from the ext. line of the banquette tread, to a point at 2,0 yds, beyond the int. crest; at this point the direction of the wall is changed, so that, being prolonged, it may cut the int. crest of the enceinte flank, at a point 4,0 yds, from

the shoulder angle. The remaining part of the embankment on this side is terminated in a glacis, the plane of which is passed through the int. crest of the enceinte curtain, and through a line on the bottom of the main ditch at 4,0 yds within the ext. side. This plane intersects the first glacis in a line ab (Pl. III. Fig. 2.), which is prolonged to its intersection b, with a line bc on the first glacis, at 6,66 yds, from the interior crest. A part of the first glacis is terminated at this line, by a plane of 1/1; the line of intersection of this plane of 1/1 with the second glacis, is prolonged to intersect the line of the wall directed on the flank, which gives the point where this wall terminates.

As the bottom of the enceinte ditch has not yet been fixed throughout, its intersection with the first glacis still remains to be determined.

77. Analysis of the double caponniere. The caponnière serves both as a communication, and as a defensive work for the ditch. As the former, the passage should admit of a convenient circulation, without being too wide, which has determined its width at 3,30 yds. The int. crests should cover the troops within the caponnière from the enemy's establishments on the crest of the bastion covered way; a relief of 9 ft. has been found sufficient for this purpose.

70. **Ramps.** The ramps leading from the plane of site to the terre-plein receive an inclination of 1/9, and they are 4.30 yds. wide. Two of them are placed on the curtain; one on the flank; and one on the face.

To construct each ramp we select its point of departure on the foot of the rampart slope; from this point we draw a line of 1/9 on the rampart-slope which is the inner line of the ramp, its outer edge being parallel to this line and 4,30 yds from it. The horizontals of the ramp are taken perpendicular to the two last lines. From these data the intersections of the plane of site and terre-plein with the ramp can be readily found (Prob. 19. Fig 24) by the usual construction for finding the intersection of two planes having their horizontals given. These intersections will give the foot and top of the ramp.

71. **Barbette. Pl. I. Fig. 7.** A barbette for five pieces is placed in the salient of the bastion. The top of the barbette is horizontal and 2.75 ft below the int. crest at the pan-coupé, its reference therefore is (82,75). It is bounded, by setting off 8 yds along the capital, from the foot of the pan-coupé, and from this point drawing a perpendicular to the interior crest of each face; these perpendiculars limit the space occupied by the piece in the direction of the capital. From the extremities of these perpendiculars, distances of 12 yds are sett off along the

interior crests; and perpendiculars of 3 yds set off, from these last points, to the interior crests; and the inward lines of the barbette are drawn through the extremities of these last perpendiculars and parallel to the interior crests. The embankment of the barbette is finished by slopes of 1/1; the intersections of which with the terre plein are found in the usual way.

Two ramps of 1/6 and 3,30 yds wide, lead from the plane of site to the barbette. The interior line of each ramp is projected in the same line as the foot of the banquette slope. The ramps are terminated on the sides by planes of 1/1. The foot of the ramp and the intersections of its side slopes with the terre-plein and banquette slope are found (Prob. 19. Fig. 24.) in the usual way.

72. **Analysis of Constructions adopted for the Enceinte.** The dimensions and form of the profile are those usually adopted for permanent works, where the embankments are formed of ordinary earth, and the revetment walls are of good masonry.

They are such as experience has shown will give durability and stability to the masonry, from the pressure of the embankments, and the ordinary causes of destructibility to which it is liable when exposed to the weather; and to the rampart and parapet the strength to resist the action of the heaviest artillery, whilst they offer to the as-

sailed every convenience for their prompt action, and the use of their arms.

The width and slopes of the ramps are regulated for the passage of artillery. Where the height to be overcome is slight, as that between the terre-plein and barbette, the slope of the ramp may be as great as 1/6, and its width be 3,30 yard. Where the height is greater, the declivity of the ramp should be proportionally less steep, and its width be 4,30 yards at least.

The position of the terre-plein with respect to the interior crests is that usually considered necessary to give shelter to the troops and materiel on it. By inclining that of the bastion, the materiel and personnel on the faces and flanks are better covered from the enfilading and ricochet fire than they would be if the terre-plein was horizontal; as a ball passing over the salient will reach an inclined terre-plein at a point farther from the salient than one which is horizontal. The height 4,50 feet, at which the salient is placed above the curtain, is as great as can be admitted in a hexagon, the least polygon to which the trace adopted is applicable; because, if placed higher, the plane of the interior crest of the bastion, prolonged back, would intersect the plane of site in a line which would fall without the salients of the two adjacent bastions of the polygon, and these bastions

would therefore not cover the one between them from reverse fire.

The slopes moreover of the terre-pleins keep them in a serviceable state, by not allowing the rain-water to collect and remain upon them.

73. Particular Conditions of the Out-works.

The out-works, besides satisfying the general conditions already laid down, are connected with each other by several minor relations of defence and suitableness, growing out of their relative positions, which give rise to many seemingly arbitrary constructions and details for each one, the bearing of which cannot be clearly understood until a description of the whole as a system has been gone into

The scarp walls of out-works, as well as their gorges where they are exposed to be turned, should not be less than 12 ft high to secure them from a sudden open assault.

Their parapets are of the same form as that of the enceinte; and for the more important ones, which are much exposed to the artillery of the assailant, of the same dimensions. In those less exposed, the thickness of the parapet may be reduced to 12 ft, or 4 yds.

The terre-pleins of the smaller out-works, which are not habitually armed with artillery, should not be less than 8 yds; those of the larger should not

be less than 10 yards.

The banquette treads of out-works which, like the caponnières and covered-ways, require a palisading for their greater security from assault, should be 6 ft. wide.

74. Tenaille. Pl. III. Figs. 1. 2. We shall adopt for the tenaille the form given it in Cormontaingné's front, placing the magistral of its curtain parallel to that of the curtain of the enceinte, and the scarp of its wings on the prolongation of the scarp of the bastion faces.

We leave a ditch of 13 yds between the gorge of the tenaille and the enceinte curtain; and one of 11 yds between each of its wings and the flanks. The magistral of its curtain is horizontal, and 13 ft above the crests of the double caponnière. The magistral of each wing is a broken line, the lowest point of it being 13 ft above the bottom of the enceinte ditch. Its gorge and the extremities of its wings are revetted. Its interior crest is horizontal throughout, and 4,50 ft below the magistral of the enceinte curtain. The thickness of its parapet 12 ft. The width of the terre plein at its curtain 8,66 yards. The parapet is terminated at the wings by traverses 12 ft thick, which extend from the interior crest to the scarp wall of the wings; the top of each traverse is on the same level as the interior crest. The traverses

are terminated towards the parapet by planes of 1/1.

To construct the principal lines of the tenaille from the preceding data, we first draw a line parallel to the enceinte curtain, and 13 yds from it, for the gorge of the tenaille curtain; another line parallel to this, and at 8,66 yds, is the interior crest, of which the reference is (63,50), as it is 4,50 ft below the enceinte magistral at the curtain.

A level passage at 31,50 ft below the magistral of the enceinte curtain and at the ref. (36,50), leads from the main ditch between the enceinte and tenaille, under this last work, and through a double caponnière in the main ditch in advance of it. The crests of the caponnière are 9 feet above the level of the passage and at the ref. (45,50); and the magistral of the tenaille curtain 13 feet above these crests and at the ref. (58,50). The interior crest of the tenaille having the ref. (63,50), is therefore 5 ft. above its magistral. The horizontal distance then between the mag. and int. crest (Art. 65.) is 12 + 3 + 1.5 = 16.5 ft, or 5.50 yds; and as these lines are horizontal their projections will be parallel and at this distance apart.

The int. crest and magistral of the wing will result from the following data. The scarp wall of the wing extends to the top of the traverse ref. (63,50); its magistral then descends, from this level in the plane of 1/1, which terminates this traverse, to a level of 13 ft

above the bottom of the enceinte ditch, which being at this part 3 ft lower than the passage of the double caponnière, and at ref. (33,50), will give (46,50) for the ref. of the lowest point of the mag. of the wing; the ref. of the point where it joins that of the curtain being, as already determined, (58,50).

To find then the lowest point of this magistral, draw a line 12 ft or 4 yds, from the extremity of the wing, for the exterior line of the traverse; parallel to this line draw another at 17 ft = 5,66 yds, which is the base of the slope of 1/1 that terminates the traverse, where this line cuts the line of defence is the required point. The horizontal distance between this point and the int. crest, calculated in the usual manner is 12 + 15 + 1,50 = 28,50 ft = 9,50 yds.

Describing from the point just found an arc with a radius 9,50 yds, and from the other extremity of the mag. another arc with a radius 5,50 yds, and drawing a tangent to these arcs, it will be the int crest of the wings.

The gorge line of the wing is not drawn parallel to the int. crest, but determined as follows. From the point of intersection of the int. crests of the curtain and wings describe an arc with a radius 8,66 yards; from the point where the enceinte curtain magi

ral prolonged cuts the interior crest of the opposite flank, draw a line tangent to this arc, which will be the direction of the required line.

The gorge wall rises to the level of the terre-plein. That which terminates the wing is limited by the planes of the parapet, terre-plein, and top of the traverse, and is termed a profile wall, from the form of its outline.

75. Analysis of Constructions &c. of the Tenaille. The tenaille is more important as a mask than as a defensive work. It covers the postern in the curtain, and also the masonry of the flanks and curtain from the enemy's batteries; which last is an essential point, if there are interior retrenchments resting either on the flanks, or curtain of the enceinte, as it will then be impracticable for an enemy to turn them, as he cannot make a breach in the enceinte behind the tenaille. As a defensive work its fire bears upon the ditches, and their counterscarps, and it thus serves to cover the retreat of the troops from the other outworks. When the ditches are dry, it is an indispensable part of the front, as the space in its rear forms a large place of arms where troops can be assembled to manoeuvre against the enemy when in the ditches.

Vauban, and Cormontaingne, we have seen so fixed the relief of the tenaille as not to mask the fire of the flanks on the breach in the bastion. It is on this principle that we have determined the position of its interior crest, and placed it at 4,50 ft below the mag. of the curtain.

In regulating its scarp wall, we have supposed, that an enemy would attempt an assault from some point in the dead space in front of it; and have therefore arranged its height, so that no part of it shall be less than 13 ft above any point that the enemy might there occupy.

The position given to its int. crest still leaves some portion of the masonry behind it exposed; but were the exposed part battered away, there would be still a formidable height of scarp left to the enceinte, the parapet of which also would be but slightly diminished in thickness by it. The portion of the enceinte flank exposed, near the shoulder angle, would be very considerable, were the exterior slope of the tenaille parapet extended to the extremity of the wing; it is to prevent this that we have placed a traverse here.

The tenaille is seldom armed with cannon, although mortars are frequently placed in it

on this account we have reduced its terre plein to 8,66 yds.

Every part of the ditch between the tenaille and curtain should be swept by the flanks. It is to satisfy this condition that we have drawn the gorge line of the wing so as to be seen by the piece that flanks the curtain of the enceinte.

The tenaille, although procuring decided advantages to the bastioned form, deprives it of one of its characteristic points, that of flanking every part of the ditch. For, in front of the tenaille, there is a dead space, where an enemy could assemble in safety to assault it. This defect, however is of trifling magnitude, since were the tenaille taken, he could not establish himself in it; and the width given to the ditch, between it and the enceinte flank, is such, as to preclude any attempt to escalade the enceinte from the top of the tenaille.

The terre plein of the tenaille is inclined, for the purpose of defiling it from the enemy's establishment on the terre-plein of the demi-lune redoubt. The inclination of the plane of defilement depends on the arrangement of this redoubt.

76 **Double caponniere Pl. II. Figs. 1. 2.** The passage of the double caponnière is 3,30 yds wide at the bottom and on the same level as the bottom of the ditch at the middle of the curtain ref. (36, 50). The int. crests of the

work are at 9 ft. above the bottom of the passage; they are horizontal, and their ref. (45,50). In the profile of the caponnière the base of the int. slope is 0,50 yd; the banquette is 2,0 yds, wide; and the base of the banquette slope 3,0 yds; the horizontal distance then between the int. crest, and the foot of the banquette slope, is 5,50 yds; which being doubled, and added to 3,30 yds, the wiltth of the passage, gives 14,30 yds, for the distance between the int. crests. The crests are drawn parallel to the perpendicular of the front, and limited by the curtain of the tenaille on one side, and a line drawn parallel to, and 3,30 yds, within, the exterior side on the other.

The embankment of the caponnière is terminated on the exterior by a glacis, which is prolonged to the bottom of the ditch. This glacis is determined, by passing a plane through the int. crest of the caponnière, and through the shoulder angle of the int. crest of the opposite bastion lowered 3 feet.

The caponnière is terminated towards the exterior side by a profile wall, along the line at 3,30 yds within the exterior side, this wall is prolonged from the ext. line of the banquette tread, to a point at 2,0 yds, beyond the int. crest; at this point the direction of the wall is changed, so that, being prolonged, it may cut the int. crest of the enceinte flank, at a point 4,0 yds, from

the shoulder angle. The remaining part of the embankment on this side is terminated in a glacis, the plane of which is passed through the int. crest of the enceinte curtain, and through a line on the bottom of the main ditch at 4,0 yds within the ext. side. This plane intersects the first glacis in a line ab (Pl. III. Fig. 2), which is prolonged to its intersection b, with a line bc on the first glacis, at 6,66 yds, from the interior crest. A part of the first glacis is terminated at this line, by a plane of 1/1; the line of intersection of this plane of 1/1 with the second glacis, is prolonged to intersect the line of the wall directed on the flank, which gives the point where this wall terminates.

As the bottom of the enceinte ditch has not yet been fixed throughout, its intersection with the first glacis still remains to be determined.

77. Analysis of the double caponniere. The caponnière serves both as a communication, and as a defensive work for the ditch. As the former, the passage should admit of a convenient circulation, without being too wide, which has determined its width at 3,30 yds. The int. crests should cover the troops within the caponnière from the enemy's establishments on the crest of the bastion covered way; a relief of 9 ft. has been found sufficient for this purpose.

As a defensive work, its fire should sweep the ditch. It is for this purpose that its embankments is arranged on the interior as an ordinary parapet, and on the exterior in the form of a glacis. Its banquette tread is made 2,0 yds wide, as it should be palisaded.

In order that the embankment of the caponniere may not, by it's relief, form dead spaces in the ditch, the plane of the first glacis is arranged so as to be swept by the artillery fire of the opposite flank. The plane of the second glacis, and the return wall are so arranged as to be swept by the fire of the curtain, and of a part of the flank.

The portion of the first glacis, near the extremity is made into a glacis coupè, leaving a sufficient thickness of parapet to cover the passage.

78. Magistrals of Demi-lune Scarp and C. Scarp

Pl.III. Fig.3. To construct the magistral of the demi-lune, two points are taken on the exterior side at 103 yds, from the perpendicular; through these points perpendiculars are drawn to the exterior side; the points where they cut the magistral of the bastion faces are joined, and on this line an equilateral triangle is constructed, its sides will give the directions of the magistral of the demi-lune. The extremity b, of the demi-lune face, is found by drawing a line at 11 yds, without the ex-

terior side.

The counterscarp of the demi-lune is parallel to the scarp and at 18 yards.

79. Counterscarp of the enceinte Pl. III. Fig. 3.

To construct the counterscarp of the enceinte, an arc is described from the salient of the bastion, with a radius of 26 yds; a perpendicular bf, of 6,60 yds, is drawn to the demi-lune face; if a tangent be now drawn to the arc, and a perpendicular be demitted from the point f, on the tangent their point of intersection f' should fall on the line drawn through the extremity of the double caponnière parallel to the exterior side. The point f' is found, by constructing the curve which is the locus, of the above conditions. The arc with the tangent drawn through f' is the magistral of the counterscarp.

80. Redoubt of the Re-entering Place of Arms. Pl. III. Fig. 3. To determine the magistral of the redoubt of the re-entering place of Arms; a line is drawn through the point b, of the d. lune face, and the extremity of the curtain, and prolonged beyond the demi-lune counterscarp. A point a, is next taken on the perpendicular, at 5,0 yds from the demi-lune salient; and through this point and a point c, assumed on the demi-lune counterscarp, an indefinite line is drawn. A line cd, is next drawn, making an angle of 60°, with the line ac. Two

lines c'd', and c'c'', are drawn, the first parallel to cd, and 4,30 yds, from it; the second parallel to ac, and at 2,0 yds, from it. If the point of intersection c', of these two lines, falls on the line drawn through b, it will be the angular point of the redoubt; and the line c' d', the magistral of one of its faces. If the point c', does not fall on the line drawn through b, then a second point c, must be chosen, and the same construction be again made. The different intersections c', will be points of a curve, which is the locus of the above conditions; and the intersection of this curve, with the line, drawn through b, will give the required point. Having the face c'd', the other face is determined as follows; a line is drawn parallel to the demi-lune counterscarp, and at 27,0 yds, from it; a point is found on this line, at 7.83 yds, from c' d'; from this point with a radius of 7.83 yds, an arc is described; a tangent drawn to this arc, from a point on the int. crest of the bastion face, at 13,0 yds, from the pan coupé, is the direction of the required face d' d'' which is terminated at the bastion counterscarp.

Pl. III. Fig. 3. and Pl. IV. Fig. 1. The ditch of the redoubt is horizontal; and the reference of its bottom is determined by supposing the plane of the superior slope of the bastion face to be prolonged to the enceinte counterscarp, finding the ref. of the point d'', in this

plane, and taking a point 4,50 ft. below this; the reference thus found is (57.90). The scarp wall of the redoubt is 13 ft. high, the ref. of its magistral will therefore be (70.90).

The salient of the interior crest is 5.33 ft above the magistral, its ref. is therefore (76,23); and its projection is evidently the point which we have already determined, at 7,83 yds from the magistral. The interior crest of the face d' d", has a slope of 2 ft, from the salient, to the extremity of this face, which condition fixes the extreme point of the int. crest at 7.16 yds, from the magistral.

Having the int. crest of one face, that of the other c' d', is found from the scale of declivity of the plane of the int crest. This scale is drawn parallel to the bastion capital, and since we have already found two points of the int. crest, by referring them to this scale, we can, as in the case of the bastion, (Art. 66) determine any required point of the other face.

A small flank of 6,0 yds, is made perpendicular to the line c' c", the line of the profile wall of the face c' d'.

The terre plein of the redoubt is 8,66 yds, wide; its gorge is revetted with a wall 13 ft heigh.

81. Analysis of the Redoubt &c. Having given the construction of the principal lines of the redoubt, we will now give the reasons in support of them.

We first observe, that on account of the ditch between the tenaille, and the enceinte flank, a breach might be opened in the curtain; by means of a battery, established on the glacis of the re-entering place of arms, if there was no mask between the ditch referred to, and this glacis. By placing the angle c, of the redoubt, on the line drawn through the extremity of the curtain and the extremity b of the demi-lune; it is readily seen, that these two works so combined cover the opening left by the ditch; since, it will be necessary to batter down, either the angle c', or the angle b, to unmask the curtain. The means here resorted to is of frequent use in fortification; and the problem may be thus stated, a line being given, which is partially covered by an existing mass, from fires in a given direction, to interpose another mass, which combined with the first, shall entirely mask the given line.

We have thus established, that the point c', shall be found on the line drawn through b and extremity of the enceinte curtain.

The communication along the gorge of the redoubt to it's ditch, is by means of stairs, placed along the profile wall c'c''. The width of the stairs is 2,0 yds. The stairs, like all other communications, to be safe, must be covered from the enemy's fire. The point where the

enemy can establish himself, to fire on the stairs, is along the crest of the demi lune covered way, around the salient place of arms. It is readily seen, from the position of the stairs and the demi-lune, that this work will partially cover the stairs; and therefore, we shall only have to interpose some other mask, combined with it, to attain the object in view. The mask used is the point c, which is the angle of masonry formed by the counterscarp walls of the demi-lune and redoubt; the ditch of the redoubt being here 4,30 yds. wide.

The position of the point a, through which the line a c is drawn, is so taken on the exterior slope of the demi-lune parapet, that the line of fire drawn through it, will pass over a man's head, at the top of the stairs.

The angle c', between the profile wall and face-wall, is made 60°, as this is the minimum angle for masonry, to give it sufficient strength. The minimum is here taken to bring the face c'd', as far in as possible, and thereby make the re-entering as deep as the case will admit of.

The object of the redoubt, is to strengthen the covered way, and sweep with its fire, the enemy's establishments on the glacis of the demi-lune. The principal works on this glacis, are the breach and

counter batteries; which occupy a space of about 140 yds. estimated from the crest of the glacis; if to this we add 10 yds, for the mean width of the covered way, we obtain the distance 27,0 yds, which is the least distance that the salient of the redoubt can be from the counter scarp of the demi-lune, to sweep the entire flank of the batteries.

The direction given to the face d' d", is such as to allow of its being flanked by the bastion face. The face is thrown out as far towards the salient of the bastion covered way as possible, for the purpose of crowding the space along the crest of this covered way, which the enemy requires for his batteries.

The redoubt being directly in front of the bastion face, its relief should be so reduced that the fire of this face may not be too much masked. To effect this, we commence by establishing the bottom of its ditch, so that the point of it nearest the bastion may just be seen by the musketry fire of the face; we then adopt nearly a minimum relief of scarp wall; finally, we arrange the interior crest of one face, so as to allow no exterior slope at one extremity and make the other at the salient 2 ft higher. This slope of 2 ft and the direction given to the scale of declivity of the int. crest, determine a plane of defilement for

the redoubt, the prolongation of which, will pass at about 3 ft, above the salients of the two demi-lunes, which are symmetrically situated with respect to the bastion capital. This is done in accordance with a principle generally adopted, that when one work is less advanced than another, and commanded by it, the plane of it's interior crest prolonged should pass 3 ft, above the points which the enemy can occupy on the advanced work, (which from the nature of the attack must fall first into his possession) so that he may not have a plunging fire into the retired work, from his establishments, which are generally about 3 ft, above the parapet of the work occupied.

The small flank of 6,0 yds, perpendicular to the profile wall, is to obtain a reverse fire on the breach made in the demi-lune.

The gorge of the redoubt is revetted to secure it from an assault.

82. Demi-lune Redoubt Pl. III. Fig. 3. and Pl. IV. Figs. 1. 2. The salient of the redoubt is 33.0 yds, from the magistral of the demi-lune; finding a point on the perpendicular, at this distance from the magistral, we obtain the salient. The magistral of the face is found, by drawing a line from this point, to the interior shoulder angle of the bastion.

To find the position of the int. crest of the face,

we must have the ref. of the magistral, and the scale of declivity of the plane of the interior crest. To determine the first, we fix the salient of the demi-lune int. crest at 3 ft, below that of the enceinte curtain this gives (70,0) for the ref. of this point. The salient of the magistral of the redoubt, is fixed at 8 ft. below the salient of the demi-lune, which gives its reference (70,0). The magistral slopes from the salient towards the exterior side, and this slope is arranged, so that the point where the magistral cuts the exterior side, shall be 5,70 ft or 1,90 yds, lower than the salient; the reference then of this point will be (64,30). Having thus two points of the mag. its position is fixed.

To determine now the int. crest, a pan coupé of 4,30 yds, is made in the salient of the redoubt, and this commands the salient of the demi-lune by 1,5 ft. The ref. then of the pan coupé, is (79,50). From the pan coupé, to the gorge of the redoubt, which is on the exterior side, the plane of the int. crest has a slope of 1,5 ft, and its scale of declivity is parallel to the perpendicular. To find the crest from the above data, we observe, that the problem is similar to the one already solved, (Art. 66.) in the case of the bastion; except, here the magistral being an inclined line, the distance of any one of its points, to the point on the int crest, contained in a profile,

is not known, since only one of the points is given. We therefore shall have to employ the following method, which applies to all similar cases.

We observe, that if the foot of the exterior slope be drawn, it will have the same slope as the magistral. Through the foot of the exterior slope then, which is known we can pass the plane of the exterior slope, whose inclination is 1/1. If any horizontal line be now drawn in this plane, we can readily ascertain the horizontal distance (Art. 66) between this line, and a known point of the int crest, contained in a profile.

To apply this to the case in point, we first draw the foot of the ext. slope, which is 0,50 yd, from the magistral; the ref. of this line at the salient, is (70.0) and at the gorge (64,30). To obtain the horizontal of the plane of the ext. slope whose ref. is, (70.0) we describe from the point (64.30), an arc, with a radius 5.70 ft, or 1,90 yds; the tangent drawn to this arc, from the point (70.0), is the required line. The ref. of the pan coupé being (78.50) its distance from this horizontal line, (the thickness of the parapet being 20.0 ft) is 26,17 ft or 8.72 yds; and the ref. of the int. crest at the gorge being (76.0), its distance from the same line is 8,22 yds; the two points thus found fix the position of the int. crest of the face.

The redoubt is made with flanks, the int crests of which are parallel to the perpendicular, 22,0 yds, in length. To find the flanks, we draw a line parallel to the exterior side, and at 22,0 yds; where this cuts the int crests of the faces, will be the int. shoulder angles of the redoubt, from which the flanks are drawn parallel to the perpendicular.

The magistral of the flank is horizontal, its position is therefore easily found.

Joining the point b, of the demi lune, with the extremity of the int. crest of the flank; we obtain the direction of the wall which terminates the flank, the ditch of the redoubt, and the extremity of the demi lune.

The terre plein of the redoubt along the face is 8,66 yds, wide; along the flank, the width is 11,0 yds. This terre plein, which is 8 ft, below the plane of the int. crest, is called the upper; to distinguish it from the remaining interiorspace, called the lower terre plein, and which is 13 ft, below the upper. A portion of the upper terre plein for a length of about 14,0 yds, from the extremity of the flank, is sustained by a wall of masonry. A portion of the interior space between the terre-pleins of the two flanks for about 6,0 yds, from the exterior side, is excavated to the bottom of the ditch.

The upper terre plein, along the face, is connected with the lower by a slope of 2/3. Two ramps, 3,30 yds, wide, with a slope of 1/6, connect the two terre pleins. The details of these constructions are best studied from (Pl. IV. Fig. 1).

The scarp wall of the redoubt is 16,50 ft, high.

83. Analysis &c the demi-lune Redoubt. The object of the demi lune redoubt has been already explained. We shall therefore simply state the reasons for the constructions employed, in determining its dimensions, &c.

The redoubt should be as advanced as possible, to see in reverse the lodgements of the enemy on the glacis of the collateral works. To effect this, its salient is taken at 33,0 yds, from the demi-lune magistral; this distance is sufficient to allow their proper dimensions to the parts of the demi-lune.

The face of the redoubt is directed on the interior shoulder angle of the bastion to have its ditch flanked by the bastion face.

In placing the salient of the magistral at 8 ft, below the salient of the demi-lune, the top of the scarp wall will be nearly on the level with the demi-lune terre plein. This arrangement will force an enemy, lodged on the demi-lune terre plein, either to lower his battery, to effect a breach in the redoubt; or else

to employ a mine for this purpose; either of which operations will cost him much labor and loss of time.

The least command has been given to the redoubt over the demi-lune, to enable the fire of the redoubt to sweep the demi lune terre plein. This command of 4.5ft. with the slope given to the plane of the int. crest, will prevent an enemy from having a plunging fire into the redoubt, from his lodgments in the demi lune.

The flanks of the redoubt are principally to procure a reverse fire on the breach in the bastion face; their length is estimated for 3 guns.

The piece nearest the extremity of one flank, should be covered by the extremity of the opposite flank, from the reverse fire which might come through the redoubt, from the enemy's lodgment on the bastion covered way.

The terre plein of the flank is made 11,0 yds as it is habitually armed.

In the outworks, wherever it can conveniently be done, bomb proof arches should be made, to serve as magazines, shelters &c. This point has been effected in the redoubt, by the position given to the lower terre-plein, by this means sufficient space is gained under the flank for a bomb proof shelter. The terre plein of the flank is sustained by a wall, which is the in

-terior facing of the shelter.

The scarp wall of the redoubt might have been reduced to the minimum dimension of 12 ft. But on account of its importance, and also not to diminish too much the interior space, it has been found that the dimensions adopted 16,50 ft best satisfy the requisite conditions. The top of the wall slopes towards the gorge, so that at the shoulder angle, it may be about 4 ft, lower than at the salient; the object of this is, to expose as small a portion of the wall as possible to the enemy's fire, through the demi-lune cut; which from its width, might admit of a breach being made in the redoubt, through it, from the enemy's lodgment on the re-entering place of arms. We shall see farther on, the manner in which the scarp of the redoubt is covered by the bottom of the cut.

84. Demi lune and its Cut. Pl.III. Fig.3. and Pl.IV. Fig.1. We will now return to the demi-lune, and finish what relates to it, and the cut in its face.

To construct the scarp of the cut, we prolong the face c'd', of the redoubt of the re-entering place of arms, to intersect the magistral of the demi-lune; joining this point, with the interior shoulder angle of the demi-lune redoubt, we obtain the magistral of the scarp.

The exterior width of the cut is found by setting off 6,60 yds, on the demi-lune magistral, from the point where it is intersected by the face c'd'. To obtain the

interior width, an arc, width a radius of 10 yds, is described, from the exterior shoulder angle of the demi-lune redoubt; a tangent is drawn to this arc, parallel to the face of the redoubt; this tangent, gives the direction of a wall, which limits the cut on the interior, and also, the portion of the demi-lune, from the cut, to the extremity of the face. From the point where the magistral of the cut intersects the tangent, we set off 11,0 yds, which is the width of the cut on the interior. This point joined with the point on the exterior, gives the counterscarp of the cut.

A parapet 20 ft thick is made behind the scarp of the cut. The relief of this parapet is so determined, that, at the highest point of the magistral, which is the point on the interior, there shall be no exterior slope; which places the int. crest 3.33 ft, above the mag. at this point. The scarp wall itself, at this point, is 13 ft above the bottom of the cut on the interior; and the interior line of the bottom is 13 ft nearly, above the bottom of the ditch of the redoubt. These conditions fix the ref. of this point of the magistral at (76, 17). The interior crest, which is horizontal, is therefore at the ref. (79.50).

The bottom of the cut has a slope of 4,60 ft from the interior to the demi lune scarp; and the

mag. of the cut is parallel to the bottom, and at 13 ft above it. This gives the ref. of the exterior point of the magistral (71,37). The magistral of the demi-lune, from this exterior point, to the point b, is held horizontal and at the same ref. (71.37). The parapet of this portion of the demi-lune face is 12 ft, thick, its interior crest is determined, by passing a plane through the int. crest of the parapet behind the cut, and allowing the prolongation of this plane to pass 3 ft, above the demi-lune salient. The preceding data are sufficient to determine the lines in question.

85. **Analysis of the Cut.** The cut isolates the part of the demi lune, near the extremity of the face, from the salient portion; this part being arranged with a parapet, behind the cut can be defended after the enemy have effected a lodgment on the demi-lune salient. The cut thus prevents the enemy from driving the besieged from the redoubt of the re-entering place of arms; which he might do, were the whole demi-lune to fall at once in his possession.

The position of the cut is so determined, as to allow the face of the demi-lune redoubt to flank the face c' d'. Widening the cut on the interior facilitates this object.

By making the interior line of the bottom

of the cut 13 ft, above the bottom of the ditch, we partially cover the scarp of the demi-lune redoubt; and place, at the same time, an obstacle in the way of an enemy, who might attempt to carry the work behind the cut, by first getting into the cut.

6.50 f.

We shall find, in speaking of the demi-lune ditch, that the slope 4,80 ft given to the bottom of the cut, still leaves a height of 15 to 18 ft between the exterior line and the bottom of the demi-lune ditch, which will secure the cut from an assault on that side. The object of this slope is chiefly so to diminish the height of that part of the demi-lune scarp from the cut, to the point D, that it may not be exposed to a battery, which can be placed on the glacis of the re-entering place of arms.

As to the int. crest, it is placed as low as possible; and is arranged to cover the interior from the plunging fire of the enemy, when he is established on the demi lune salient.

86. **Demi-lune. Pl. IV. Fig. 2.** To return to the demi-lune, of which only the magistral, and the relief of the interior crest at the salient have been determined. We place the magistral, at the salient, 11,40 ft, below the int. crest; and as the ref. of the latter is (78,0) the ref. of the former will be (66,60). The magistral has a slope of 1,50 ft, from the salient to the cut; and the int. crest is

parallel to the magistral; this condition will determine the int. crest, when the salient is known; and this is arranged so as to have a pas coupé of 4,30 yds.

The scarp wall of the demi-lune is 22,50 ft high.

The terre plein is 11,0 yds, wide. A ramp 3,30 yds, wide, having a slope of 1/6, leads from the ditch of the demi lune redoubt to the demi lune terre plein. The position and arrangement of the ramp are shown in Pl. IV. Fig. 2.

The terre-plein is finished by a slope of earth, instead of being sustained by a wall. This slope is thus arranged; the part terminating the ramp, is a plane of 1/1; the portion in the angle is formed by an inclined cylindrical surface, which touches the two interior lines of the terre plein, the width of the ditch, at the salient of the redoubt, terminated by the base of the cylinder, is 4,30 yds. The remaining portion of the slope is formed of a warped surface, the elements of which are horizontal, connecting the cylinder, and the plane of 1/1. It may be as well to mention, that this construction is purely arbitrary. The object being to have the portion of the slope in the salient as gentle as practicable, so that this part may serve as a ramp for infantry.

87. Analysis of the demi-lune &c. The principal properties of the demi-lune were mentioned in describing Cormontaingne's system; and it was there observed, that

he improved upon Vauban's, by augmenting the dimensions of the demi-lune. Engineers since Cormontaingne finding that the demi lune still admitted of being enlarged with advantage have accordingly so determined it's dimensions, that it may be thrown as far to the front as possible, but keeping the breach, which an enemy may make in it's face, within the range of the musketry of the bastion face. In large fronts, like this under consideration, the demi lune may be thus made to cover about 30 yds of the bastion faces from the shoulder angle; and thus secure retrenchments resting against this part from being turned by a breach made near the shoulder angle.

These considerations limit the salient angle of the demi lune to 60°; and place the salient, at not more than 210 yds, from the bastion face, as this distance will bring the breach at about 180 yds, from this face or within the effective range of musketry.

The demi-lune thus arranged, places the bastions in all cases in strong re-enterings; but when the angles of the polygon are very obtuse, the faces of the bastions prolonged, fall within the salients of the demi lunes, and are therefore not easily enfiladed. The fire from the demi lune is very effective on the enemy's works along the bastion capitals. Finally, it is a work of which the enemy can only obtain possession, after great labor,

and loss of time; and when carried, it is with great difficulty that he can render it tenable; as it is exposed to the fire of the enceinte, within a short range.

The demi-lune with these advantages, is not without defects. Its faces, from their position, are exposed to an enfilading fire; it deprives the curtain of all action on the exterior ground, and it is only when the angles of the bastion are very open, that the re-entrings, formed by the demi lunes, become of a formidable character. The glacis of the demi lune covered way forms a ridge, which is serviceable to the enemy by masking his works, on one side of the ridge, from the fire of the collateral works on the other.

Having noticed these general properties of the demi-lune, we will now proceed to our particular constructions.

In terminating the face at 11,0 yds, from the exterior side, we allow for a passage made along the extremity of this face, and for a face-cover for the bastion; of which mention will be made farther on; moreover, we unmask the flank of the demi lune redoubt, intended to defend the breach in the bastion face by a reverse fire.

We reduce the command of the curtain over the demi lune to the minimum; and to obtain as much

interior space for the demi-lune redoubt as practicable, we reduce the height of the interior crest above the magistral to 11,40 ft, the interior space evidently depending on this height. The terre plein is reduced to 11,0 yds, partly for the same reason, and partly, to give an enemy great trouble in establishing a battery on it, as to do this he will be obliged to cut away a part of the parapet, and will thus expose the rear of the battery to the fire from collateral works.

We terminate the terre plein by a slope of earth for economy, and because this slope is favorable to offensive movements, made to drive the enemy from the breach.

It is not probable that an enemy would attempt to carry the demi lune by escalade, it is well however to provide against such an attempt, in so important a work; it is chiefly on this account that the scarp wall is made 22.50 ft, high. This dimension also allows the bottom of the cut to be so placed that it can be swept by the fire of the demi lune redoubt.

88. Face-cover of the bastion. Pl. II. Fig. 3. & Pl. IV. Fig. 1. By prolonging the bastion counterscarp to the point P', it serves as a face cover, to the bastion scarp masking it from the fire of the breach battery, erected around the salient place of arms of the demi lune covered way. The

angle f', of the face cover is placed on the same line as the extremity of the double caponnière, for the purpose of covering the troops, as they débouche from the caponnière, from the enemy's establishment along the glacis of the bastion covered way. The height of the wall, at the point f', is so determined, as to intercept the enemy's fire, coming from a point 3 ft, above the crest of the bastion covered way, and passing at 7,50 ft, above the bottom of the ditch, at the extremity of the caponnière. From the point f', to the gorge of the redoubt of the re entering place of arms, the top of the wall ascends; so as to cover the ramp, leading from the ditch, to the top of the counterscarp at ff'; and also the passage, leading from this point, to the gorge of the redoubt.

89. **Single caponière and traverse in the demi-lune ditch.** This last passage is also covered from the enemy's works on the glacis of the demi lune salient place of arms, by the crest of a single caponnière, in the ditch of the demi lune. The glacis of this work is determined, by passing a plane through the point (83.40) of the int. crest of the bastion face, found, by producing back the demi lune magistral, and through two other points, in the demi lune ditch; one taken at 13 ft, below the ditch of the redoubt of the re entering place of arms, the other, at about 16,50 ft below the cut in the demi lune. The crest

of the caponnière is held in this plane; and in projection, is drawn parallel to the magistral of the face-cover; so as to allow space enough between it and the foot of the wall, which terminates the demi lune face, for a banquette tread of 2 yds, and its slope of 1/1; all of which will require about 4,30 yds. The passage referred to is 4,30 yds, wide. In order that it shall be covered by the crest of the caponnière the bottom of it must be at least 8 ft. below the crest.

The preceding construction subserves two purposes. We observe, from the position of the glacis, that it is swept by the fire of the bastion face; so that the dead space, which was noticed at this point of the demi lune ditch, in Cormontaingne's system, is here removed. The other point is, to cover the troops crossing the demi lune ditch from the fire coming from the demi lune salient place of arms.

As it is important to keep this passage open, even after the enemy obtains possession of the demi lune; a traverse is placed at the extremity of the caponnière, so as to cover the postern which communicates with the terre plein of the redoubt of the re entering place of arms. A portion of this traverse has to be sustained by a wall, which is so arranged, as to afford the least possible shelter to an enemy, who, from behind it,

might attempt to carry the redoubt by the gorge.

The face cover is terraced, the embankment being 2,50 yds, thick at top, and sloped inwards towards the passage.

The details of this part of the construction being rather complicated, will be better understood by refering to Pl. IV. Fig. 1. than by any written explanation.

90. Mask in the Demi lune Redoubt Ditch Pl. IV. Fig. 1. To cover the curtain wall from a fire through the opening between the flank and tenaille, coming from a battery established on the demi-lune terre plein, we place an embankment in the ditch of the demi-lune redoubt, raising the wall, which separates this ditch from that of the enceinte, high enough to support the embankment. The embankment is sloped on top and terminates in a point near the demi-lune cut; on the side towards the redoubt, it is terminated by a slope, the foot of which is 4,30 yds, from the foot of the redoubt scarp. The crest of the embankment is terminated on the line drawn throug the shoulder angle of the redoubt and the angle of the tenaille.

The bottom of the ditch between the embankment and redoubt is about 12 feet above that of the enceinte ditch, which secures the demi-lune from being turned through this ditch.

By separating the embankment from the demi-lune redoubt, this work is secured from an attempt to carry it from the embankment. For the same reason the gorge wall of the work behind the cut is raised 18 feet above the top of the embankment. A like expedient is resorted to in all similar cases, as in the gorge wall of the redoubt of the re-entering place of arms; and the counterscarp of the demi-lune cut, as shown in the details on Pl. IV. Fig. 1.

91. Covered-ways. Pl. V. Figs. 1. 2. The bastioned covered way is 11,0 yds, wide; the int. crest being drawn parallel to the counterscarp.

The crests of the re-entering place of arms are drawn parallel to the magistral of the redoubt, and 20 yds, from it.

The crest of the demi-lune covered way is a broken cremaillere, or crotchet line. The short branches of the cremaillere, are 6,60 yds long and are placed so as to be perpendicular to the direction of the demi-lune capital. Before constructing this cremaillere line, a few remarks will be necessary on the traverses of the covered way, and their connection with the crotchets.

92. Remarks on the traverses and the defiles. The object of the short branches of the crotchets is to cover the defiles, or passages, between the ends of the traverses

and the crest of the covered way; and also to give a column of fire in the direction of the demi-lune capital. To fulfil this last object, the short branches are provided with a banquette, its slope is only 1/1, to bring the crest of this branch as near as practicable to the traverse; a passage of 2,0 yds, is left between the foot of the banquette slope, and the wall, which terminates the end of the traverse; the direction of this wall is parallel both to the long and short branches of the crotchets; leaving a passage between it, and the long branch, 2,0 yds, wide.

If then, to find the short branch we take the base of the interior slope 15 ft, the banquette tread 6 ft; the base of the banquette slope 3,50 ft, and the width of the defile 6 ft; we shall obtain 17 ft, or 5,66 yds, for the distance between the crest of the short branch, and the wall that terminates the traverse, parallel to this branch.

The portion of the long branch, opposite the traverse, is without a banquette &c; for the purpose of leaving the least distance between the crest of the crotchet and the traverse; so that the defile may be covered, in the best manner. To effect this, a vertical wall is made, parallel to the end of the traverse, and at 2,0 yds, from it, to leave space for the defile; this wall sustains the earth, but is not built up higher

point a, on the demi lune. The line n o, is the interior crest of No. 1. The exterior crest n'o', is parallel to it, and at 6,66 yds.

From the point n' as a centre, with a radius of 5,66 yds, an arc is described; a tangent drawn to this arc, perpendicular to the demi-lune capital, gives the short branch of the crotchet.

To construct Traverse No. 2, from the extremity of the short crotchet, just found, with a radius of 6,60 yds, an arc is described a tangent drawn from the point a, to this arc, will give, by its intersection o with the counterscarp, a point of the int. crest of No. 2; the int. crest is drawn from this point, perpendicular to the tangent, Note, for convenience, we shall designate by the same letters as in No. 1, the corresponding points of all the traverses. The exterior crest n'o', is drawn at 4,33 yds, from n o,

To obtain the crotchets, from any assumed point n' of the exterior crest, with radii of 2,66 and 5,66 yds, two arcs are described; tangents are drawn to these arcs; one from the inner extremity of the short branch of No 1, to the arc of 2,66 yds; the other, to the arc of 5,66 yds, and perpendicular to the demi lune capital. If these two tangents intersect on the line l'm', then the point n', is one point of the end No. 2; and the line n n',

is drawn parallel to the long branch. If the tangents do not intersect on l' m', then, some other point n', must be chosen, and a similar construction made, until the intersection is found on the line l' m', which will be the salien angle of the crotchets.

To construct No 3, and its crochets, a point is taken on the short branch of the crotchet last found, at 4,30 yds, from its salient angle; from this point, an arc is described, with a radius of 4,50 yds, a tangent drawn to this arc, from the point a, will give the point O, on the counterscarp where the int. crest of No.3 is to be dra perpendicular to the tangent. The exterior crest of this traverse is at 4,33 yds, from the int. crest.

The short branches of the crotchets of No.3, and 4, have the same direction as the others; but they are limited by two lines, one drawn parallel to the cou scarp, and at 11,0 yds, from it, the other at 6,60 yds, f this, measured on a perpendicular to the demi lune capital. These two lines being drawn, the position of the salient and re-entering angles of the crotchets, th rest upon them, will be found by a construction, simi to the one just described.

The re-entering angle of the crotchet of No. 2. is cut off; by drawing a line through the centre of the arc and parallel to the tangent drawn to it fro

To construct No 4 we commence by finding the foot of its exterior slope; this is done, by describing an arc from the angular point c', of the redoubt of the re entering place of arms, with a radius of 4,30 yds; a tangent drawn to this arc, through the demi-lune salient, being produced to the covered way, gives the foot of the exterior slope. The int. crest of No. 4, is parallel to this line; its position is found, by allowing 4,66 ft 1,55 yd, for the base of the exterior slope, and 20 ft or 6,66 yds, for the thickness of parapet. Having the exterior crest, and int. crest, the point n', and the crotchets, are found as in the preceding cases.

The interior crest of the salient place of arms is on the line l m, produced; which is at 11,0 yds, from the counterscarp. A pan-coupé of 4,30 yds, is made in the salient.

94 Traverse on the Bastion Cov. Way. Pl. V. Fig. 1. There yet remains the traverse, on the bastion covered way. To construct it, and its crotchets, a line t r is drawn at 5,50 yds, parallel to the crest of the bastion covered way; the extremity of the traverse n n', is drawn parallel to t r, and 2,66 yds, from it. From the point n, on the crest of the re entering place of arms, the int. crest of the traverse is drawn perpendicular to the bastion counterscarp. The exterior crest is 20 ft, or 6,66 yds, from

the int. crest.

To find the other branch of the crotchet; n n' is taken equal to 5,0 yds, a line is drawn through r and n', and produced to s, on the crest of the bastion covered way; an arc with a radius of 2,66 yds, is now described from n', and the tangent s t, drawn to this arc, is the branch required.

95. Command of the Cov. Way and Traverses. Pl.V. Fig.2. To arrange the relief of the covered way and traverses, the following method is pursued. The salient of the demi-lune covered way is 7,50 ft lower than the salient of the demi lune; the ref. of this point then is (70,50). The interior crests of the salient place of arms, of traverse No. 4, and the long branch between Nos. 3 and 4, are held in the same plane; the scale of declivity of which, is parallel to the demi-lune capital; its inclination being determined, by placing the extremity of the long branch just referred to 0,75 ft, lower than the salient of the demi lune covered way.

The short branch of the crotchet of No. 3, has the same reference as the salient of the covered way (70.50). This line, the int. crest of No. 3, and the long branch, are held in the same plane; whose scale of declivity is parallel to the demi lune capital; and whose inclination is such, that being produced, it will pass 3ft

above the salient of the covered way.

The relief of No. 2, and it's crochets, is determined in the same manner, as in the preceding case. The ref. of the short branch being fixed at (70,20).

The salients of the bastion covered way, and the re entering place of arms, command the salient of the demi lune covered way by 1,50 ft. Their ref. therefore is (72,0).

96. Remarks on the covered ways and traverses. The demi lune covered way is made wider towards the re entering, to cover the traverse defiles with more ease. The witth of 11.0 yds, of the portion near the salient, makes the covered way so narrow, that should an enemy find it necessary to lower his breach battery into the covered way, to effect a practicable breach, he will be obliged to cut away a part of the glacis, to obtain sufficient room for his works.

The counterscarp of the redoubt of the re-entering place of arms is a slope of earth, so as to make the re entering place of arms more spacious, by joining the ditch of it's terre plein.

The interior crests of the re entering place of arms, and it's two traverses, are held in the same plane; whose scale of declivity is parallel to the bastion capital. This plane produced, passes 3 ft, above the salients of

of the caponnière is held in this plane; and in projection is drawn parallel to the magistral of the face-cover; so to allow space enough between it and the foot of the wa which terminates the demi lune face, for a banquette tread of 2 yds, and its slope of 1/1; all of which will re quire about 4,30 yds. The passage referred to is 4,30 y wide. In order that it shall be covered by the crest of caponnière the bottom of it must be at least 8 ft. be the crest.

The preceding construction subserves two pu poses. We observe, from the position of the glacis, tha it is swept by the fire of the bastion face; so that the dead space, which was noticed at this point of the de lune ditch, in Cormontaingne's system, is here remo The other point is, to cover the troops crossing the demi lune ditch from the fire coming from the den lune salient place of arms.

As it is important to keep this passage open even after the enemy obtains possession of the demi lune; a traverse is placed at the extremity of the c niére, so as to cover the postern which communicate with the terre plein of the redoubt of the re enteri place of arms. A portion of this traverse has to be s tained by a wall, which is so arranged, as to afford t least possible shelter to an enemy, who, from behind

might attempt to carry the redoubt by the gorge.

The face cover is terraced, the embankment being 2,50 yds, thick at top, and sloped inwards towards the passage.

The details of this part of the construction being rather complicated, will be better understood by refering to Pl. IV. Fig. 1. than by any written explanation.

90. Mask in the Demi lune Redoubt Ditch. Pl. IV. Fig. 1. To cover the curtain wall from a fire through the opening between the flank and tenaille, coming from a battery established on the demi-lune terre plein, we place an embankment in the ditch of the demi-lune redoubt, raising the wall, which separates this ditch from that of the enceinte, high enough to support the embankment. The embankment is sloped on top and terminates in a point near the demi-lune cut; on the side towards the redoubt, it is terminated by a slope, the foot of which is 4,30 yds, from the foot of the redoubt scarp. The crest of the embankment is terminated on the line drawn through the shoulder angle of the redoubt and the angle of the tenaille.

The bottom of the ditch between the embankment and redoubt is about 12 feet above that of the enceinte ditch, which secures the demi-lune from being turned through this ditch.

By separating the embankment from the demi-lune redoubt, this work is secured from an attempt to carry it from the embankment. For the same reason the gorge wall of the work behind the cut is raised 18 feet above the top of the embankment. A like expedient is resorted to in all similar cases, as in the gorge wall of the redoubt of the re-entering place of arms; and the counterscarp of the demi-lune cut, as shown in the details on Pl. IV. Fig. 1.

91. Covered-ways. Pl. V. Figs. 1. 2. The bastioned covered way is 11,0 yds, wide; the int. crest being drawn parallel to the counterscarp.

The crests of the re-entering place of arms are drawn parallel to the magistral of the redoubt, and 20 yds, from it.

The crest of the demi-lune covered way is a broken cremaillere', or crotchet line. The short branches of the cremaillere', are 6,60 yds. long and are placed so as to be perpendicular to the direction of the demi-lune capital. Before constructing this cremaillere' line, a few remarks will be necessary on the traverses of the covered way, and their connection with the crotchets.

92. Remarks on the traverses and the defiles. The object of the short branches of the crotchets is to cover the defiles, or passages, between the ends of the traverses

and the crest of the covered way; and also to give a column of fire in the direction of the demi-lune capital. To fulfil this last object, the short branches are provided with a banquette, its slope is only 1/1, to bring the crest of this branch as near as practicable to the traverse; a passage of 2,0 yds, is left between the foot of the banquette slope, and the wall, which terminates the end of the traverse; the direction of this wall is parallel both to the long and short branches of the crotchets; leaving a passage between it, and the long branch, 2,0 yds, wide.

If then, to find the short branch we take the base of the interior slope 1.5 ft; the banquette tread 6 ft; the base of the banquette slope 3,50 ft, and the width of the defile 6 ft; we shall obtain 17 ft, or 5,66 yds, for the distance between the crest of the short branch, and the wall that terminates the traverse, parallel to this branch.

The portion of the long branch, opposite the traverse, is without a banquette &c; for the purpose of leaving the least distance between the crest of the crotchet and the traverse; so that the defile may be covered, in the best manner. To effect this, a vertical wall is made, parallel to the end of the traverse, and at 2,0 yds, from it, to leave space for the defile; this wall sustains the earth, but is not built up higher

than within 1,50 ft, of the crest; the earth has the na
val slope of 1/1, from the crest, to the top of the wall;
base of this slope consequently, will be 1,50 ft, and a
of 0,50 ft is left, on the top of the wall. Adding toge
these distances, we obtain 2,66 yds, for the distance be
the crest of the long branch, and the wall parallel
it, which terminates the traverse.

93. Traverses on the demi-lune covered

There are four traverses on the demi lune covered way
which, to avoid repetitions, we will designate, as No
No. 2, No. 3. & No 4. No 1. being nearest the re-enteri
place of arms.

To construct the crotchets of traverses No
2; a line l m, is drawn, parallel to, and at 13,0 yds,
the demi lune counter scarp; parallel to this line, an
at a distance of 6,60 yds, measured on a perpendicul
to the demi lune capital, a second line l'm' is draw
The salient and re-entering angles of the crotchets, b
No 1 and 2, rest on these two lines.

To construct traverse No 1, a line n n', is
parallel to l'm', and at 2,66 yds; from the point
intersection n, of this line, with the crest of the re
tering place of arms, a line n o, is drawn, so th
its intersection o, with the demi-lune counterscar
shall be perpendicular to a line drawn from o, t

point a, on the demi lune. The line n o, is the interior crest of No. 1. The exterior crest n' o', is parallel to it, and at 6,66 yds.

From the point n' as a centre, with a radius of 5,66 yds, an arc is described; a tangent drawn to this arc, perpendicular to the demi-lune capital, gives the short branch of the crotchet.

To construct Traverse No. 2, from the extremity of the short crotchet, just found, with a radius of 6,60 yds, an arc is described a tangent drawn from the point a, to this arc, will give, by its intersection o with the counterscarp, a point of the int. crest of No. 2; the int. crest is drawn from this point, perpendicular to the tangent, Note, for convenience, we shall designate by the same letters as in No. 1, the corresponding points of all the traverses. The exterior crest n' o', is drawn at 4,33 yds, from n o,

To obtain the crotchets, from any assumed point n' of the exterior crest, with radii of 2, 66 and 5,66 yds, two arcs are described; tangents are drawn to these arcs; one from the inner extremity of the short branch of No 1, to the arc of 2, 66 yds; the other, to the arc of 5, 66 yds, and perpendicular to the demi lune capital. If these two tangents intersect on the line l' m', then the point n', is one point of the end No. 2; and the line n n',

is drawn parallel to the long branch. If the tangents do not intersect on l' m', then, some other point n', must be chosen, and a similar construction made, until the intersection is found on the line l' m', which will be the salien angle of the crotchets.

To construct No 3, and its crochets, a point is taken on the short branch of the crotchet last found at 4,30 yds, from its salient angle; from this point, an arc is described, with a radius of 4,50 yds, a tangent drawn to this arc, from the point a, will give the point O, on the counterscarp where the int. crest of No. 3 is to be dra perpendicular to the tangent. The exterior crest of this traverse is at 4,33 yds, from the int. crest.

The short branches of the crotchets of No. 3, and 4, have the same direction as the others; but they are limited by two lines, one drawn parallel to the cou scarp, and at 11,0 yds, from it, the other at 6,60 yds, fr this, measured on a perpendicular to the demi lune capital. These two lines being drawn, the position of the salient and re-entering angles of the crotchets, th rest upon them, will be found by a construction, simi to the one just described.

The re-entering angle of the crotchet of No. 2. is cut off; by drawing a line through the centre of the arc and parallel to the tangent drawn to it from

To construct No 4 we commence by finding the foot of its exterior slope; this is done, by describing an arc from the angular point c', of the redoubt of the re entering place of arms, with a radius of 4,30 yds; a tangent drawn to this arc, through the demi-lune salient, being produced to the covered way, gives the foot of the exterior slope. The int. crest of No. 4, is parallel to this line; its position is found, by allowing 4,66 ft 1,55 yd, for the base of the exterior slope, and 20 ft or 6,66 yds, for the thickness of parapet. Having the exterior crest, and int. crest, the point n', and the crotchets, are found as in the preceding cases.

The interior crest of the salient place of arms is on the line l m, produced; which is at 11,0 yds, from the counterscarp. A pan-coupé of 4,30 yds, is made in the salient.

94 Traverse on the Bastion Cov. Way. Pl. V. Fig. 1. There yet remains the traverse, on the bastion covered way. To construct it, and its crotchets, a line t r is drawn at 5,50 yds, parallel to the crest of the bastion covered way; the extremity of the traverse n n', is drawn parallel to t r, and 2,66 yds, from it. From the point n, on the crest of the re entering place of arms, the int. crest of the traverse is drawn perpendicular to the bastion counterscarp. The exterior crest is 20 ft, or 6,66 yds, from

the int. crest.

To find the other branch of the crotchet; n n' is taken equal to 5,0 yds, a line is drawn through r and n', and produced to s, on the crest of the bastion covered way; an arc with a radius of 2,66 yds, is now described from n', and the tangent s t, drawn to this arc, is the branch required.

95. Command of the Cov. Way and Traverses. Pl.V. Fig.2. To arrange the relief of the covered way and traverses, the following method is pursued. The salient of the demi-lune covered way is 7,50 ft lower than the salient of the demi lune; the ref. of this point then is (70,50). The interior crests of the salient place of arms, of traverse No. 4, and the long branch between Nos. 3 and 4, are held in the same plane; the scale of declivity of which, is parallel to the demi-lune capital; its inclination being determined, by placing the extremity of the long branch just referred to 0,75 ft, lower than the salient of the demi lune covered way.

The short branch of the crotchet of No. 3, has the same reference as the salient of the covered way (70.50). This line, the int. crest of No. 3, and the long branch, are held in the same plane; whose scale of declivity is parallel to the demi lune capital; and whose inclination is such, that being produced, it will pass 3 ft

above the salient of the covered way.

The relief of No. 2, and it's crochets, is determined in the same manner, as in the preceding case. The ref. of the short branch being fixed at (70,20).

The salients of the bastion covered way, and the re entering place of arms, command the salient of the demi lune covered way by 1,50 ft. Their ref. therefore is (72,0).

96. Remarks on the covered ways and traverses. The demi lune covered way is made wider towards the re entering, to cover the traverse defiles with more ease. The witth of 11.0 yds, of the portion near the salient, makes the covered way so narrow, that should an enemy find it necessary to lower his breach battery into the covered way, to effect a practicable breach, he will be obliged to cut away a part of the glacis, to obtain sufficient room for his works.

The counterscarp of the redoubt of the re-entering place of arms is a slope of earth, so as to make the re entering place of arms more spacious, by joining the ditch of it's terre plein.

The interior crests of the re entering place of arms, and it's two traverses, are held in the same plane; whose scale of declivity is parallel to the bastion capital. This plane produced, passes 3 ft, above the salients of

the covered ways of the two collateral demi lunes.

The crests of the bastion covered way are in the same plane; whose scale of declivity is parallel to the bastion capital. This plane prolonged also passes 3 ft above the same points as the last mentioned.

The traverses serve as masks to cover the terre plein of the covered way from ricochet shots; for this purpose Nos. 2 and 3 may be only 4, 33 yds, or 13 ft thick. But the other traverses, which close the re entering and salient places of arms, being more important, have a thickness of 6, 66 yds. As the general height of the traverses is 2, 66 yds, it is readily seen that, if we suppose the extreme limit of ricochet firing to be an angle of 1/10, the traverses should not be more than 26, 6 yds, apart, in order that a shot striking the crest of one traverse, may imbed itself in the one immediately in rear of it.

The traverses also serve as a defence; and for this purpose, are made like an ordinary parapet. To enable the besieged to defend the covered way, they are palisaded, and barriers are placed at the defiles. As the means of protracting the defence, is only effective when the defiles are perfectly secured from the fire of the enemy, established along the crest of the salient place of arms; the reason for the particular con-

struction given for each traverse will now be apparent. The interior crests of Nos. 1, 2 and 3 are so arranged, that they can concentrate their fire on the salient place of arms; and each traverse is so combined with the demi-lune, as effectually to mask the defile of the one in rear of it. The defile of No. 1, is masked by No. 2; and a passage of about 2,0 yds, at the foot of the banquette slope of No. 1, is covered; so that the troops can pass through this defile in perfect safety.

The defile No. 2, is not so easily covered by No. 3. To effect it, we have to cut off the inner angle of the crotchets, and suppress the banquette slope, substituting in its place steps; by these means, we cover a passage of 1,0 yd, and place No. 3 not too far from No. 2.

As it is not practicable to cover the defile of No. 3, the position of No. 4 is determined, so as to make the salient place of arms as spacious as possible. This is done, by placing No 4 in a position, to allow its exterior slope to be swept by the fire of the bastion face, penetrating between the salient of the demi lune and the angle of the redoubt of the re entering place of arms.

The defile of the traverse on the bastion covered way, is arranged to prevent any line of fire penetrating through it into the re-entering place of arms.

The precautions which we have here taken, would

be still insufficient, could the enemy, in possession of the crest of the salient place of arms, have a plunging fire upon the covered way behind the traverses. It is to prevent this, that the interior crests of the different traverses, and their respective crotchets, are held in the same plane; which is so arranged, that the terre plein shall be defiled from the enemy's lodgment on the crest of the salient place of arms. This arrangement necessarily places the terre plein between the traverses on different levels; small ramps will therefore be necessary to pass from one level to the other. They are placed at the defiles.

The salient place of arms is inclined for the purpose of partially defiling it from the trench cavalier.

Finally the traverses are sustained on the side of the counterscarp by a profile wall, which is the prolongation of the counterscarp wall; and they are terminated at the other extremity by a wall, so arranged as to make the defile convenient as a communication.

97. Counterscarps of the bastion and demi-lune. Having determined the relief of the covered way which we may observe, is such that they cover all the masonry of the scarps, and at the same time, are so low, that an enemy could not by the ordinary methods in use obtain a plunging fire from them upon the terre plein of the works in their rear, we can now finish what

remains to be said on the ditches.

The top of the counterscarp wall should be at least 8 ft, below the planes of the interior crest of the covered way, and the height of the wall for the body of the place, should not exceed 24 ft and for the demi lune, it may be reduced to 18 ft. These dimensions will therefore be assumed, as the greatest that can be allowed, with a proper regard to economy. And a continuous wall of these heights may be regarded as a powerful auxiliary obstacle, in securing the works from all attempts at surprise.

Adopting the limit of 24 ft, for the counterscarp of the bastion; we see that the bottom of the ditch at the foot of this wall, is higher than at the foot of the scarp wall of the bastion face; and as the bottom of the ditch, at the extremety of the double caponnière, has already been determined; we must connect these different levels by planes, combined in the most simple manner.

98. Cunettes and bottoms of the Ditches Pls. IV V. A cunette 4,0 yds, wide at top, and 3 ft deep, is made in the main ditch to serve as a drain; a culvert, or small arch of masonry, is made under the double caponnière, connecting the cunette on the opposite sides of it. The cunette is placed parallel to the bastion face; the bottom of the ditch having a slope of 1,50 ft, from the foot of the scarp wall, to the edge of the cunette, and a slope from the

opposite edge up to the foot of the counterscarp wall. These details will be best understood by referring to Pls. IV. V. Figs. 1. The slopes here given, serve to keep the bottom of of the ditch dry; they assist in rendering the breach, made in the bastion face, rather steeper than if the bottom were horizontal; and in the passage of the ditch, the enemy's work is more exposed, than if the bottom were not sloped from the foot of the counterscarp wall to the cunette.

The demi-lune ditch is arranged upon similar principles. A cunette and culvert are placed in it, to convey the rain water from it into the main ditch.

99. Planes of the glacis The glacis of the covered way now be considered. One principle is chiefly to be attended to in disposing the different planes of the glacis. They should all be swept by the artillery fire of the works immediately in their rear, and by the musketry fire at least of the bastion face.

The glacis of the bastion covered way should be swept by the artillery of the bastion face.

The glacis of the re-entering place of a should be swept by it's redoubt.

The glacis of the demi lune is more difficultly arranged; owing to the cremaillère form of the interior cr The best method seems the following; planes are pa

through each long branch, so as to be swept by the artillery fire of a portion of the face of the demi-lune; these are connected by another series of planes, which are passed through the salient point of each crotchet; below the plane of musketry fire of at least one half of the bastion face, and below the plane of artillery fire of a part of the demi-lune face.

It is readily seen, from the nature of this problem, that it admits of many solutions. In selecting amongst them, the following considerations may serve as guides. When the planes of the glacis have a very gentle slope, they are better seen by the works in their rear; but the construction is more expensive, on account of the greater quantity of embankment.

When the slope is more steep, the enemys works on the glacis are better exposed to the reverse views of the collateral works, although not so well seen by those directly in rear of the glacis; but the quantity of embankment is smaller.

100. **Outlets or sortie passages.** To communicate from the covered way with the glacis, an outlet or sortie passage is cut in the least exposed face of the re entering place of arms; and one also on the long branch, between the 3^{d} and 4th traverses. They are from 3,30 to 4,0 yds wide. The cut is about 6 ft, in depth, the

earth being sustained on each side by a profile wall. The bottom of it is a ramp leading from the terre plein of the covered way to the top of the glacis. As the outlet is closed by a barrier, it should be arranged at the bottom, to allow the barrier free play in opening and shutting.

101. **Communications.** There is no part of a fortification where more care and judgement are required than in the dispositions made to communicate from the interior with the outworks. The safety of the besieged essentially depends on a proper disposition of the communications, which should afford every facility for offensive movements, and at the same time, a secure and easy means of retreat.

Besides the ramps, which have already been explained, posterns, and stairs, form a part of the system of communication.

Posterns, as we have already stated, are arched communications of masonry, made under the rampart or terre plein. When these communications are required for the passage of artillery, they should be at least 10 ft. wide, and 8 ft. high under the crown or key of the arch. When for infantry, they may be reduced to 4 ft. in width, and 6 ft in height under the key. The arch of the postern is general

a semi circle, or what is called a full centre arch. To be bomb proof it should be at least 3 ft thick through the masonry of the arch, and be covered by at least from 3 to 4,50 ft of earth.

Stairs are only used in situations where ramps cannot be placed; as for example, to communicate with the interior of works, the gorges of which are revetted.

Each step is generally formed of a single block of stone, which is 2,0 yds long in the clear, 0,30 yds, in width, and 0,20 yds, high. From these dimensions of the height or rise, and width, or tread, of each step; we obtain the following formula for the base of a flight of steps, when the height between the two landings is given, $3/2\ h - 0{,}30 = base$.

Stairs are not so convenient as ramps; and they are moreover liable to be easily put out of order by the effects of shot and shells.

102. **Communication of the enceinte with the ditch.** We will now take up the communications of the different parts of the front, commencing with the body of the place.

The postern of the enceinte leads through the middle of the curtain, descending from the plane of site to the ditch. The inclination of the bottom should never exceed 1/6. The bottom should not

come out upon a level with the bottom of the ditch, but about 6 ft above it; a wooden ramp being used to descend from the postern to the bottom of the ditch.

The width of this postern should be 12 feet; both on account of the greater circulation through it, and because it may be used as a bomb proof shelter for the troops on duty.

The entrance to this postern, both towards the ditch, and the interior, is by door ways; one through the scarp wall, which closes the postern towards the ditch, and one through a vertical wall of masonry, at the extremity of the enceinte terre plein, which closes the mouth of the postern towards the interior. The earth of the rampart slope is cut away, to leave the passage to the postern free. The sides of the cut are sustained by wing walls, which make a small angle with the vertical wall of the postern mouth. The door way may be 7 ft. wide, and 7.50 ft. high the postern itself being 10 ft. under the key.

For more security, a partition wall, with a door way, is sometimes made across the postern, about the middle point. The leaves of the folding doors here have loop holes to fire upon an enemy, should be by a surprise gain possession of the exterior door way.

103. Communication with the Kenaille.

A postern, for the passage of artillery, is made under the tenaille, and leads to the double caponnière. Two stairs are placed at the gorge of the tenaille, to communicate with its terre plein.

104. Communication with the terre plein and ditch of the demi-lune redoubt. Two stairs are placed at the gorge of the demi-lune redoubt, to communicate with its terre plein. A postern for artillery, leads from the main ditch, to the ditch of the redoubt, under its flank; for the communication between the main ditch and the demi-lune.

105. Communication from the enceinte ditch with the exterior. To communicate with the covered ways, a ramp of earth sustained by walls, is placed along the wall that terminates the demi-lune and its redoubts. This ramp is separated from the extremity of the face cover, by a cut 4,30 yds, wide.

106. Communication with the demi-lune cut. The communication with the work behind the demi-lune cut, is by a postern, and stairs for infantry, which lead from a point on the ramp just described to the terre plein of the work; passing in a winding direction, under the terre plein and parapet of the work.

107. Communications of the redoubt of the

re-entering place of arms. &c. The passage behind the single caponnière, in the demi lune ditch, has already been described. This passage leads to a postern for artillery made through the face of the redoubt, to its ditch. From the ditch a ramp for artillery leads to the terre plein of the re entering place of arms. At the angle of the redoubt on the demi lune ditch, stairs are placed to ascend to its ditch, a ramp for infantry leads from the ditch on this side to the terre-plein.

To ascend to the terre plein of the redoubt a small postern for infantry is made through the face to the ditch, being placed along side of the postern just described; from this a winding postern and stairs lead to the terre-plein of the redoubt.

The foregoing, with what has been said respecting the caponnièrs, traverse defiles &c, completes the description of the communications of the front. We shall now close this subject with a recapitulation of the principal conditions which should regulate every system of communications.

108 **Remarks on the communications.**

1st The communications should never, from their position, compromise the safety of the encente.

Frequent instances could be cited of works which have been surprised by an enemy obtaining

possesion of the gates. Therefore too many precautions cannot be taken to secure the principal outlet from the body of the place, from similar attempts. It is on this account, that the postern in the body of the place is arranged as has been described, to frustrate any sudden attack that might be made upon it.

2d. The communications should admit of a convenient circulation of the besieged.

To subserve this purpose, the dimensions, slopes &c, of the posterns, ramps, and other similar works, should be convenient for the service to which they are applied; and they should be placed in such positions, as lead directly to the point to be arrived at. In examining the form, dimensions, and position of the ramps &c, of the front, it will be found, that these conditions are well satisfied.

3d. The position chosen for any communication should be such, that when an enemy gets possession of it, he may obtain no advantage by it.

To be useless to an enemy, the communication, when in his power, should not offer a shelter for his works; nor enable him, to carry them on with more ease. We shall obtain this end, by placing the communications in a position to be enfiladed by the fire of the works in their rear; and so ar-

-ranging them, as to preserve the counterscarp wall unbroken; by which means, we shall also avoid offering any facility for attempts at surprise.

4th The communications should be covered from every point where an enemy might establish himself during the whole period that they can be of service to the besieged, and they should be swept by the fire of the enceinte.

Without these precautions, an enemy might cut off all communication from the enceinte with the outworks; and in cases of retreat, the troops could not derive any assistance from the enceinte if he attempted to press upon them.

In covering the communications, we should employ in preference existing masses; which form a part of the general arrangement of the works. We have examples of this, in the manner in which the débouche from the double caponnière, and also those from the traverse defiles are covered. In the first case, by the angle of the counterscarp wall, and the salient of the bastion; and in the second, by the angle of the profile walls of the traverses, and the demi lune salient. Sometimes, a special mask has to be raised; an example of which is seen in the traverse at the gorge of the redoubt

of the re entering place of arms, which covers the door of the postern of the redoubt.

5th They should be so placed as not to compromise the retreat of the troops.

This is effected, by placing the communication in the re enterings; which are the most secure points; as an enemy to arrive at them will have to brave a powerful column of flank fire. Barriers, gates, and movable bridges of timber should be placed at suitable points; to cut off one communication from another; and thus arrest the progress of a pursuing enemy.

6th Finally, each work should be independent of every communication, except the one destined for its particular use.

This is an important object, as it prevents an enemy should be succeed in gaining possession of a communication leading through it, from seizing upon the work itself. We have examples of this arrangement, in the postern through the face of the redoubt of the re entering place of arms, which leads to the exterior; and which is not connected with the small postern, destined for the service of the redoubt itself; another example of this arrangement, is in the postern leading from the main ditch, to that of the demi-lune redoubt, for the service of the demi lune; this

postern does not interfere with the safety of the redoubt

By examining the communications of the front generally, according to these conditions, it will be found, that their arrangement is as judicious as the nature of the problem seems to admit.

109. **Interior retrenchments.** The front as it has now been described, appears to be of a character to protract the siege to the longest duration. When however a breach is made in the enceinte, although military usage, and a point of honor require of the garrison to sustain at least one assault, the consequences of defeat are of too serious a character, to expect such an effo unless a place of safety is provided, into which the garrison may retreat after defending the breach and obtain an honorable capitulation. On this account, and also to lengthen the defence, interior retrenchments are made in the bastions. These works may be either of a temporary, or permanent character; but it is generally conceded, that the latter class alone offer a serious obstacle to the enemy. The former moreover require that the bastions should be full; and that the intrenchment should be thrown up during the siege an undertaking of great difficulty, both from the annoyance of the enemy's fire, and the fatigued state of the garrison, occasioned by its ordinary duties.

We shall therefore, only describe the permanent interior retrenchments with a revetted scarp and counter-scarp; and which may be regarded as an element of a regularly fortified front

Interior retrenchments may be divided into four classes. 1st Those that rest against the faces of the bastions. 2nd Those that rest against the flanks. 3d Those that rest against two adjacent curtains. 4th Those that comprehend several bastions.

110. First class resting on the faces. Pl. VI. Figs. 1. 2. & A, B Fig. 3. The first class may be of the form of a cavalier, shut in by cuts across the bastion faces; or an inverted redan; or finally, if the bastion is very open, a small bastion front. Of this class, the cavalier has been generally employed, as by means of the cuts across the bastion faces, which are arranged with parapets, the top of the breach in the bastion face may be defended; the cavalier, receiving so great a relief, as to give it a plunging fire upon the enemy's works on the glacis of the bastion covered way.

This class present the advantages of defending the breach within a short distance; and by enclosing the flanks of the bastion within them they preserve the flanking arrangements of the body of the place until the retrenchment is carried. The principal objection

to them is, that by a breach made at the shoulder angl the enemy can turn them.

111. Second class resting against the flanks. Pl.VI. Fig: 4.C. The second class may be of an inverted redan; or of a small bastion front; or finally of a redo resting against the middle of the flanks, its faces having such a direction that its ditch may be swept by the fire of the flanks of the adjacent bastions.

The last form admits of defending the breac within a short distance; it preserves also the flanki arrangements of the enceinte, and can only be turned by a breach made in the curtain. Its ditch is not qu well defended by the musketry of the opposite flank; on account of the distance moreover it will be neces- sary to cut down a part of the scarp wall of the flan for this purpose, which will make the height of the wall less than 11.0 yds.

112 Third class resting on two adjacent curtain Pl.VI. Fig. 4. D. The third class is usually of the form of a bastioned front; but as the fire of its faces would be masked by the curtain of the enceinte, it is general best to construct the front simply with a curtain an two flanks.

This class, being thrown farther from the sa of the bastion, does not defend the breach so direct

as the two preceding, but it is stronger, and forces an enemy to employ more means to carry it. From it's dimensions, it will require more space on the interior, and will be also more expensive, than either of the preceding forms.

113. **Fourth class enclosing several fronts.** The fourth class, which is placed in the rear of several bastions of the enceinte, or properly several fronts, is a kind of second enceinte within the first. An arrangement of this character would of course require a peculiar locality; and would seldom find an application.

Having given the general outline of interior retrenchments, we shall conclude what remains to be said on the subject by describing the cavalier retrenchments.

114. **Cavalier retrenchments with cuts in the bastion faces. Pl. VI. Figs. 1. 2.** The faces of this work are parallel to those of the bastion in which it is placed; it's ditch should be about 18 ft, below the bastion terre plein; it's scarp wall about 24 ft high. And we may here observe, that all interior retrenchments, to oppose a serious obstacle to an enemy, should have revetments of about these dimensions.

The interior crest of the face should be so high,

that the line of fire drawn from the salient of the cava
to the salient of the bastion covered way, shall pass abo
the bastion salient. By placing the counterscarp of the
cavalier at 14,0 yds, from the interior crest of the bastio
allowing 11,0 yds, for the width of the ditch; and maki
the bottom of the ditch 18 ft, below the bastion terre
plein; it will be found that the ref. of the bottom of the
ditch will be (58,50); the scarp wall being 24 ft high,
the ref. of its magistral will be (82,50). Now if the ref
of the interior crest be taken at (97,50), or 15 ft. above
the magistral, its projection will be at 33,16 ft, or 11,06
yds from the magistral; and as both the lines are
horizontal, parallel to it; Drawing then three lines
parallel to the bastion, int crest at the distances above mentio
ed, we obtain the projections of the counterscarp, sca
and interior crest of the cavaliere. The position give
to the interior crest will satisfy the condition first la
down.

The interior crest of the flank is also horiz
tal; it's ref. therefore is (97,50); the direction of the fla
is perpendicular to the line of defence of the bastion,
the flank moreover, is not revetted like the face, but
is terminated, by prolonging its exterior slope to the
bastion terre plein; the lowest point of the foot of this
exterior slope, will therefore be about (73,00) the ref. of

the bastion terre plein at the extremity of its flank; the least width of the bastion terre plein, between its flank, and that of the cavalier, should be 14,0 yds. If then, from the interior angle of the curtain with a radius of 14,0 yds, an arc be described; and a tangent be drawn to this arc, perpendicular to the line of defence; this tangent may be taken as the horizontal of the exterior slope of the cavalier flank, whose ref, is (73,0); the interior crest of the flank is drawn parallel to this horizontal, and at 41,16 ft or 13,72 yds from it; which will be the distance found by calculation; the thickness of the parapet being 20 ft, the superior slope 1/6, and the exterior slope 1/4.

The length of the flank is found by drawing through the angle of the curtain, a line parallel to the line of defence, and where it cuts the interior crest of the flank, will be the extremity of the flank.

To terminate the gorge of the cavalier, a plane of 1/1 is passed, through the extreme points of the interior crest of its flanks. A passage of 4,30 yds. is left on the bastion terre plein, at the gorge of the cavalier, to communicate with it; and also to preserve an uninterrupted communication between the two adjacent curtains. A ramp 3,30 yds, wide, with a slope of 1/6 leads from the gorge of the cavalier, to its terre plein. This ramp is generally placed along the capital of

the bastion.

115. Cut in the bastion face. Pl. VI. Figs. 1. 2.

To determine the cut across the bastion face, a distance of 13,0 yds, is sett off from the shoulder angle of the bas along its interior crest; from this point a line is drau making an angle of 100°, with the interior crest; th line being produced to intersect the magistral of the cavalier face, is the interior crest of the parapet beh the cut. The ref. of this line where it intersects the magistral is (82,50), the ref. of the other extremity be (84,0); it is held in the same plane with the porti of the interior crest of the bastion, between the shou angle and the point at 13,0 yds, from it; the ref. of shoulder angle remaining, as already found; it u be seen, that the plane of these two lines produce passes 3 ft, above the bastion salient. The thickne of parapet is only 12 ft. The magistral of the scarp of the cut is horizontal, its reference being (76.50). From the preceding data, its position is easily dete mined. A line drawn parallel to the magistral, a at 6,60 yds from it, will be the counterscarp of th cut. The counterscarp wall of the cut is carried to the top of the bastion face and forms a profile u to sustain the earth. The scarp wall of the cut is o the same height as that of the cavalier; the botto

of the cut will therefore be referenced (52.50), a portion of the ditch of the cavalier face has the same reference; this portion is found, by holding at the level (58,50) that part of the bottom of the ditch which is swept by the fire of the parapet behind the cut.

This arrangement of the ditch of the cavalier, subjects only a part of it to the fire of the parapet behind the cut. By placing the door of the postern, that, leads into the cavalier ditch, at the point where the small vertical wall separates the two levels, it will be partial-ly covered from the enemy's lodgment on the bastion terre plein.

The object of the cut is similar to the one in the demi lune face; it confines the enemy to the salient part of the bastion; preventing him from ex-tending his works along the bastion terre plein, to turn the cavalier by it's gorge; so that to obtain posses-sion of this work, he must make a breach in it's face.

There is a dead space in the cavalier ditch, which might offer some facilities, were the enemy to attempt to carry the parapet of the cut by escalade. To remedy this defect, it has been proposed to place a crenated gallery behind the scarp wall of the cut, to flank the entire ditch.

Summary of the Principles and essential Details involved in the Bastioned Front.

116. The chief object of the preceding discussions has been to present the general principles and most important details of the art of fortification, as agreed upon by the highest authorities among military engineers, in their applications to a particular case; that of the bastioned enceinte, with its essential dependencies, adopted to a horizontal site with dry ditches. In doing this many seemingly arbitrary conditions, growing out of the relation of defence between the component parts of the system, had to be satisfied; and geometrical constructions of a somewhat complex character had to be resorted to, as a means of solution of the proposed problem. As it is of the first importance to the student that he should not confound what pertains to the principles and rules of the art with that which is merely auxiliary, it is the purpose of the summary about to be made to present the main conclusions arrived at which belong to the art itself divested of every thing that is subsidiary; omitting such details as involve no important principles.

1st. The enceinte of every permanent work should present an uninterrupted line of scarp wall which, when the enceinte ditch is dry, should be at least 30 feet in height above the bottom of the ditch; and when

the ditch is constantly supplied with water to the depth of 6 feet, the top of the wall should be 18 feet above the water surface.

2d. All the approaches to the work beyond its ditch, within the effective range of its fire, as well as every point of the ditch itself should be completly swept by this fire.

3d. The scarp walls of the enceinte and out-works should be sheltered from the enemy's artillery, to the latest moment, by earthen masks.

4th. All parapets should be proof against the heaviest projectiles; for this purpose a thickness of 20 feet is usually considered sufficient for those formed of ordinary earth.

5th. The greater the command given to the parapet, and the nearer it is brought to the scarp, the more plunging and more effective will be its fire upon the enemy's approaches; and the greater will be the obstacle it offers to an escalade.

6th. The terre-plein of the rampart should be masked by the parapet from the enemy's view; its width should be sufficient for the infantry and artillery service; convenient communications for the same objects should be established between all its parts, and also between it and the parade, or portion of

the site within the enceinte.

7th When the plan of the enceinte is of the bastioned form the relief, curtain, flanks and lines of defence should bear such relations to each other that the foot of the entire scarp wall shall be brought within the range, and under the fire of the rampart gun and cannon. This object will be effected by keeping the lines of defence within the limit of 300 yards; placing the flanks so far apart, and giving them such a position with respect to the curtain, that their artillery fire shall attain a point at least as low as 1,50 ft above the foot of the scarp at the middle of the curtain, and sweep the ditch from this point to the salients opposite the flanks.

8th The size of the fronts will depend upon the relative dimensions of the curtain, flanks and lines of defence. The greatest front will result from combining the least curtain, the least flank, and longest line of defence. The shortest will result from the combination of the least flank, and least curtain, the face being zero.

9th All outworks, except the covered-ways, should be regarded rather as accessories than as indispensable additions to the enceinte. When properly placed, they strengthen weak points of locality, and delay the

progress of the enemy, by forcing him to gain possession of them before he can advance beyond the points they occupy.

To effect these objects, their scarps, and also the gorges of such as are liable to be turned by the enemy, should be of masonry, and not less than 12 feet in height. They should be commanded by the enceinte; and, as far as practicable, be flanked by its musketry. The more retired of these works should command the more advanced; and where, from any more important condition of defence, as, for example, in the cases of the redoubt of the re-entering place of arms, and the tenaille, this rule has to be violated, the retired work should be thoroughly defiled from any establishments the enemy may be presumed to make on the advanced one by which it is commanded.

10.th The covered ways are regarded as essential to the defence; as without them the communications between the enceinte and the exterior would not be secure; nor could offensive movements be made without extreme peril. By affording advanced covers for the garrison, they give the means of annoying the enemy by sharp shooters, and sorties in small parties, by which his approaches may be greatly retarded. Their embankments from the

best and, in most cases, the only masks, for the sca
of the works in their rear, against the enemys can
until he can plant his batteries on the very crest
the glacis.

To mask the covered ways from enfilading
plunging fires, and to afford the means of disputi
with obstinacy their possession by the enemy, their c
should command the exterior ground by at least 6
and, in turn, be commanded by at least 4, 50 feet
the works in their rear; shot proof traverses of the c
form of parapets should be placed at suitable point
along their terre plein; they should be provided w
a strong palisading, besides barriers at all their a
and outlets, they should be thoroughly swept by t
musketry of all the works in their rear; and their
re-pleins should be defiled from all commanding p
that may be presumed to fall into the hands of the
whilst it is still essential to the defence to hold on
any part of the covered ways that may be exposed
these points.

11th The glacis should be so arranged that it c
be thoroughly swept by the artillery and musk
of the portions of the enceinte and outworks from
a fire can be brought to bear upon it. For this p
pose the various surfaces of which the glacis ma

composed should be so combined that their intersections shall present no hollows, nor ridges of which the enemy might take advantage for shelter, in pushing forward his works.

12th The demi lune, when of large size and judiciously arranged, forms a very important addition to the defence. By covering the curtain and a portion of the bastion faces near the shoulder angles from the enemy's artillery, it secures the main outlet from the enceinte from surprise, and preserves entire, up to the latest moment, a portion of the bastion scarp upon which retrenchments may rest. The bastion salients being thrown into strong re-enterings formed by adjacent demi-lunes, the enemy is forced to take the latter before he can attempt the assault of the enceinte; and in cases where the bastion salients are obtuse and the demi-lunes very salient, the latter mask the bastion faces from enfilading views, and thus secure them from all fire but that of counter-batteries.

These advantages to the defence are the more decided as the demi-lune is the larger and more advanced. It is in view of these considerations, and to bring the breach which the enemy may make in the demi-lune face under the musketry of the enceinte, that the dimensions and form of the demi-lune,

in the front, were assigned it. The height of scarp 22.50 ft, which this work receives in the front, is given both in view of its importance, as a security against escalade, and to obtain an efficient cut across its face.

13th The demi-lune redoubt is an important element of strength to the demi-lune, as by covering the retreat of troops from it by its fire, they are encouraged to make a more obstinate resistance. By its arrangement with flanks, it also becomes an important addition to the enceinte; as the reverse fire from the flanks on the breach in the bastion face will force the enemy to carry the redoubt before he can risk an assault on the breach. The command of the redoubt, and the height and position of its scarp wall are arranged in the front with the view of subserving the preceding objects; of securing the work from a coup-de-main; and of forcing the enemy to resort to mining to open a breach in it.

14th The tenaille is an indispensable addition to all fronts of attack. Without it the postern in the curtain would not only be insecure but nearly unserviceable so soon as the enemy gains a position on the glacis from which his fire can be brought to bear on its outlet.

By covering the scarp of the curtain and flanks from the fire of the breach batteries at this position it enables the assailed to form either permanent, or temporary retrenchments, resting on these parts, under cover of which the defence of the breach in the bastion face can be made with vigor, and the possession of the bastion be disputed to the last moment. It secures to the assailed a sheltered place of arms, between it and the curtain, which they can use for sorties against the enemy's works in the ditches. The relief of the tenaille is so regulated that it shall not mask the fire of the flanks on the bastion faces, whilst, at the same time, efficient cover is afforded to the scarp of the curtain and flanks.

15th The redoubt of the re-entering place of arms adds greatly to the strength and security of the covered ways, in their defence against open assaults, by covering by its fire the retreat of the troops from them. From the retired position of this work, it can be occupied even after the demi-lune is in possession of the enemy; provided there is an efficient cut in the demi-lune face, and that the redoubt can be defiled from the establishments of the enemy on the parapet of the demi-lune. The redoubt should be so placed that, in connection with the demi-lune, it shall cover that portion of the curtain which is exposed through the ditch between

the tenaille and the enceinte flank. The crest of the redu
should mask, as little as practicable, the fire of the bas
face on the glacis in advance of it.

16th The cut in the demi-lune face secures th
redoubt of the re-entering place of arms from be
turned. Its position should be so chosen that th
face of this redoubt, which ranges on the demi-l
may be flanked through it by the fire of the dem
lune redoubt; which fire should also sweep the bo
of the cut. A parapet is thrown up behind the c
both to arrest the enemy, and to annoy his estab
ments in the demi-lune; for this purpose the para
should command the demi-lune salient; and the
terre-plein behind it should be defiled from the
point.

17th As from motives of economy, the embar
ments of the front should be formed of the excav
of the ditches, the size of these last will in a great d
depend upon the volume of the first. The relative
sions of the depth and breadth of the ditches m
be made to depend, in some measure, on the cons
of defence. Narrow and deep ditches present more di
ficulties to the enemy for forming practicable eas
breaches than the reverse kind; but deep ditches
seldom be obtained without, to some extent, sacri

a through flanking. When these last are adopted for the enceinte, they form deeper and stronger re-enterings between the collateral demi-lunes, in advance of the bastion salients; whilst they, at the same time, contract the space along the glacis, in their prolongation which the enemy must occupy for his counter batteries against the enceinte flanks. Where water can be used for the defence of the ditches, it is more advantageous to increase the width at the expense of the depth, as a greater obstacle is thus opposed to the passage of the ditch by the enemy.

Dry ditches are more favorable to an active defence than wet; but the last, when the depth of water that can be constantly maintained in them is over 6 feet, secure the works from attempts at surprise, even after practicable breaches are formed. Ditches which can be filled and emptied at pleasure may be made to combine the advantages of both kinds of defence.

The ditches of the different works should present no communications through which an enemy might penetrate from one into that of another, and thus assault the works by the rear; and, for greater security from attempts at surprise, the counterscarps should be revetted, giving the walls a height from

15 to 24 feet in very important works.

The demi-lune ditch is made as narrow as practicable so as to cover with more ease the defiles around the traverses.

18th The communications should be of convenien dimensions, and of easy access. They should be so placed, as to bring the point to be reached beyond them, directly in view; be swept by the fire of the works in their rear; be covered from the fire of all points that the enemy can occupy whilst they are needed; be secure from surprise, and from being approached in their rear by the enemy; and not compromise the safety of any work through which they may lead.

Open communications can be better defended than those which are covered. The latter should be bomb proof.

Influence of Irregularities of Site on the Forms and Combinations of the Elements of Permanent Works.

117. In treating the subject of permanent fortification the same order is usually followed as in the discussion of temporary fortification: viz. 1st An exposition of the general principles with their applications to a horizontal site. 2d The various modifications of detail occasioned by irregularities of site as presented in nature. 3d The various accessory means of strengthening weak points, called for by peculiar circumstances of locality, which either preclude the application of the ordinary means, or require others in addition of them.

118. Whether the site is perfectly level within the range of the fire of the work, or is irregular, the same general conditions are to be satisfied in each case, in order that the work shall have all the efficiency of which it is capable. These are: 1st That every point exterior to the defences, over which the enemy must approach them, or from which he can annoy them by his fire, should be brought under the fire of the defences. 2nd That no point of the defences shall be left unguarded by their own fire, or present any position where the enemy, obtaining temporary

shelter from fire, may gain time to renew an on
3d That the troops and materiel within the def
shall be sheltered from the enemys fire in any pa
he may take exterior to them.

119. The manner of satisfying these conditi
on a horizontal site has been fully discussed in
preceding articles. In irregular sites, the engine
frequently obliged not only to modify the forms
dimensions of the bastioned system, as adapted
a horizontal site, but to forego the advantages
herent in this system, and adopt some other ar
arrangement which will lend itself better to the
locality; resorting to the many expedients presentes
the accessory means for satisfying the conditions
good defensive combination.

The problem presented for solution to th
gineer in irregular sites is frequently one of no or
complexity; demanding a minute and laborious
of the natural features of the position in their
tions to the defence; connected with a tentative
cess of which the object is so to modify the plan
and details ordinarily adopted, as to adapt them
the best manner to the given position. No rules
of a very general character can be laid down f
the guidance of the engineer in such cases. Of t

class the following are the most obvious and essential, and, when practicable, should be adhered to.

120. 1st. It has already been observed that, from the means used in the attack of permanent works, the more plunging the fire of the work the more efficacious will it prove in retarding the enemy's progress. The efficiency of this fire will depend upon two causes, the greater or less command of the work over the point to be attained, and the direction of the ground to be swept with respect to the lines by which it is swept. As to the command of the work over the exterior ground, it has already been shown that motives of economy restricts it, in most cases, within very narrow limits, where to obtain it artificial embankments have to be employed. To augment therefore in the greatest degree this element of the defence, advantage should be taken of the natural features of the locality, by placing the principal lines, from which the exterior ground can be seen, on the most commanding, or highest points of the site. If, with this position given to the principal lines, the ground swept falls, or slopes towards them, the most favorable combination for an efficacious plunging fire will be obtained; for, with this direction of the ground, the enemy will meet with

for greater difficulty, to put himself under shelter by works, than where the ground falls, or slopes from line by which it is swept; as the surface, in the case descending in the rear of the cover thrown by the enemy, will be screened to a greater extent than in the former, where it rises in the rear of the

The general rule therefore which the en is to take as a guide, in order to satisfy the cond of bringing the exterior ground under an efficacious fire from the work, is to place the principal lines of work on the most commanding points of the site, a in such directions as to bring the exterior ground to swept in a position sloping towards these lines; a this will generally be best effected by placing the sa nants of the work on the most commanding and sa points of the site; as, in this position of the sali the faces, which are usually the principal lines on the exterior ground, will occupy the salient and manding portions of the site, whilst the re-entera being thrown on the re-entering and lower portio of the site, will be in the best position for sweeping the ground immediately in advance of the faces; at the same time they will be masked by the fac from the enemy's view, and thus preserved from serious injury up to the moment when their actio

may be rendered most effective; that is when the enemy, despite the fire from the faces, has succeeded in planting himself upon points on which this fire cannot longer be brought to bear.

121. 2nd The condition of leaving no point of the defences unguarded by their fire will depend, in a great degree, for its fulfilment on the same rule as the preceding. But where both conditions cannot be satisfied, the distant defence should be sacrificed to the near, as upon the latter the more or less of obstinary of resistance depends, since the fire of the work and the action of the garrison are the more effective as the point to be guarded is the nearer to the defences.

122. 3d The condition that the troops and materiel within the defences shall be sheltered from the enemy's fire, from all commanding points without, will depend upon the relative positions of the principal lines and the exterior commanding points; and, as far therefore as it can be done, without sacrificing either of the preceding and more important conditions, the plan of the work should be so arranged that the principal lines shall present themselves in the most favorable direction to the exterior ground to avoid plunging, enfilading, or reverse views upon

their terre-pleins from any point of it.

To effect these objects, when the work is
the vicinity of commanding heights within can
range, and the crests of these heights, as seen fro
the work, present a nearly horizontal outline,
principal lines of the work, fronting the height
should receive a direction as nearly parallel as
ticable to that of the commanding crests: when
outline of the crests presents a nearly continuou
but one which declines, or slopes towards the site
work, the principal lines towards the height sh
receive a direction converging towards the point
the line of the crests, as seen, if prolonged wou
join the site. The reasons for the positions assi
to the principal lines, in these cases respectively,
not, at a first glance be obvious; but by examin
the relative positions of the crests of the height
of the principal lines, as here laid down, it
without difficulty be seen that they can be bro
in the same plane, and the latter be so placed as to
a nearly uniform command to the parapets of th
cipal lines over the site; and that by keeping the te
pleins of these lines in planes parallel to the one
which the crests of the heights and those of the n
are held and at suitable levels below it, the para

will be made to cover the terre-pleins from the fire of the heights in the simplest manner.

The foregoing general methods, for determining the direction of the principal lines fronting commanding heights, so as to cover from direct fire, in the easiest manner, by their parapets, the space to the rear occupied by the troops and materiel, present, at the same time, the simplest cases of the adaptation of the plan of a work to the features of the locality, to subserve the object in view. In most cases, all that can be done is to avoid giving such directions to any of the principal lines, as shall be favorable to enfilading, or reverse views of the enemy; which may be effected by so placing them that their prolongations shall fall on points where the enemy cannot establish his works; or on those which, if occupied by him, will afford disadvantageous positions for his batteries either for enfilading, or reverse fires.

123. Defilement of Permanent Works. The greater importance of so adapting the plan and command of permanent works to the features of irregular sites as to satisfy the conditions of sweeping thoroughly by their fire all approaches exterior to the defences, and completely flanking the latter, seldom places it in the

power of the engineer to fulfil the condition of w
drawing the interior of the defences from either en
or reverse views, from points without, by a modi
of either the plan, or the command. To shelter th
pleins which would be exposed to these fires, as u
as such as would be attained by a plunging fire in
resort must be had to the usual expedients of defi
that is giving to the terre-pleins such positions
respect to their parapets that the troops and m
upon them will be screened from a plunging fire
front by the parapets; and, when the terre-pl
are exposed to either enfilading, or reverse view
placing earthen traverses, or other masks, as to
tercept these views, and cover the troops &c. fro
the enemy's projectiles.

124. The defilement of permanent works like
of field works proposes the same end, and employ
the same means. They differ mainly in their
tical details; the latter being reduced to a simple
tical operation on the field, whilst the former, fro
the usually greater complexity of the arrangeme
of permanent defences, requires the aid of mather
science and demands results of extreme accuracy.

125. For the solution of all problems of the
of permanent works, the engineer requires: 1st D

limit exterior to the defences beyond which the effect of the enemy's fire may be regarded as so uncertain as to be neglected. 2nd The presumed positions within this limit that the enemy may take up to bring his artillery to bear upon the works. 3d An accurate topographical map of all the ground within the above limits, as given by its horizontal curves referred to a plan of comparison. 4th The magistrals and interior crests of the works, as either definitively or approximately arranged, referred to the same plane.

126. The limits beyond which the enemy's fire, from the usual siege guns, may be disregarded, owing to the uncertainly of long ranges, are 1500 yards where the work is exposed only to a direct, or front fire; and 2000 yards when open to a reverse fire. When the terre-pleins therefore are covered, either by their parapets, or other means, from batteries at these distances, they may be considered as offering shelters sufficiently secure for the troops &c upon them.

It may happen that there are points beyond these limits, but within the extreme range of siege guns, which, from their positions, it would not be safe to disregard; but these will from exceptional cases, and, when they occur, will be treated in the same

manner as those within the limits.

127. The surface embraced within the limits and the line of defences may be divided into three zones; one lying between the limits and the position of the 1st parallel of the attack, which is usually 600 yards from the salients of the line of defences; the second between the positions of the 1st and 2nd parallels, or to a line within about 300 yards of the salients just mentioned; the third between the positions of the 2nd and 3d parallels, or up to within 60 yards of the salients. In any position that the enemy can take up for his batteries within the first zone, it is usually estimated that he will not throw up any parapet with a greater command than 10 feet over the ground on which it is placed. Granting this, the muzzles of his guns behind the parapets will not be raised higher than 6 feet above the natural surface; so that, assuming the surface of this first zone to be raised 6 feet above its true position, this may be regarded as the limit, vertically, within which the enemy's lines of fire will be restricted; and therefore if the interior of the defences is covered from the fire within this limit, the troops &c. will be secure. That the enemy will not, in all likelihood, elevate his guns above this limit will seem probable, when it is tak

into consideration that any advantage he might derive from doing so would not be commensurate to the labor this would cost him. For let us suppose the enemy to have taken up a position for an enfilading battery, at 1000 yards from any salient, to enfilade one of its faces of the length of 100 yards; and suppose that he should decide upon raising his guns 3 feet, or one yard above the limit just laid down; a simple proportion will show that, by this increase in the height of his battery, he will be able to attain a point at the farther end of the face only 3, 6 inches lower than he would have done in the position of the assigned limit; an advantage which considering the uncertainty of the fire at the assumed range; would hardly compensate the additional labor of giving to his works the additional command.

In the zone between the 1st and 2nd parallels, the limit may be reduced to 2, 5 feet, for at this distance from the defences their fire is so destructive and certain that the enemy cannot, without great loss of life and time, raise the parapet of his batteries higher than 8 feet above the natural surface.

From the 3d zone the musketry of the enemy may be brought to bear upon the defences; and, from this position, during sorties from the defences, or at any

other opportune moment when their fire is not active the enemy might mount on the parapet of his trenches, and from these deliver his fire. This would be his line of fire about 10 feet above the natural surface. The limit vertically of this zone may therefore be assumed at 10 feet above the natural surface.

The limits of the dangerous ground exterior to the line of defences may be marked off on the topographical map of the site (Pl. VII. Fig. 1.); by drawing lines concentric with the line connecting the most advanced salients of the defences, and at the respective distances from it of 1500, or 2000 yards, (as the fire may be brought to bear on the front, or rear); 600 yards; 300 yards; and 60 yards; and then considering the references of the horizontal curves of the ground, within the zones thus marked off, to be increased 6 feet in the first; 4.5 ft. in the second; and 10 feet in the third.

128. In the defilement of each part separately of the line of defences, those portions alone of these zones must be regarded as dangerous which are embraced within arcs, or other lines drawn at the foregoing distances from the salients, or the faces of the part to be defiled. It may also happen that within the limits of dangerous ground for any

portion of the line of defences, there may be other portions which, from their position, may mask the portion to be defiled from all the dangerous points beyond them; in which case the points thus shut off need not be regarded, in effecting the operations of defilement. Of for example, (**Pl. VII. Fig. 1.**) the limits of dangerous ground for the demi-lune **A** being marked off, it is found that the demi-lune **B** masks the demi-lune **A** from all fire that might come from the ground beyond **B**, then this portion of the zones of danger need not be regarded in defiling **A**. To ascertain this point, it will be only necessary to conceive a right line to be so moved as to rest in each of its positions upon a point of the interior crest of **A** and on one of **B**, and if this line, in all its positions, passes above the surface of the dangerous zones beyond **B**, then will **B** serve as a mask for **A**.

129. In covering masonry from the enemy's artillery 800 yards is usually regarded as the longest range at which destructive effects can be produced; and also that within this distance the angle of incidence of the ball on the surface must be greater than 45°, to do serious injury to it.

130. In the defilement of works of limited interior capacity, as, for example, the redoubt of the re-entering place of arms, the double caponnière, and the like, which

are moreover not habitually occupied by troops, the extr
limits may be reduced to 1000, or 1200 yards.

131. Within the limits of the zones of danger p
may be found for direct or front; for reverse; and for
enfilading fire. If the two faces, for example, of a
be prolonged to intersect the extreme limit of dange
ground, the sector which they embrace may be termed t
limits of direct, or front fire; since, from every position
can be taken up within this sector, a direct fire ca
can be brought to bear upon the two faces. The tw
sectors which lie adjacent to this way be termed
limits of lateral, or reverse fire, since they afford positi
from which a reverse fire can be obtained against on
the faces, and a front fire upon the other. It is al
only within these last limits that positions for enfila
the terre-pleins of the faces can be obtained.

132. The problems of defilement which present t
selves for solution may embrace one or more of these c
in any example; depending upon the relative posit
of the interior crest of the work to be defiled, and of
dangerous ground embraced within the foregoing li
In the case of only direct fire, the terre-pleins can b
screened by their parapets alone; in that of a rever
fire on one face alone, its terre-plein, in some cases.
be screened by a suitable position given to the parape

the other; where both are exposed to this fire, one or more traverses must be resorted to as a screen; against an enfilading fire on one face alone, a portion of the parapet of the other, near the salient, may be a sufficient protection in some cases; but, for the most part, traverses, placed across the terre-plein, will be the only remedy.

133. It does not come within the scope of this summary to examine the many cases of defilement which may arise from inequalities in the site; those alone will be discussed which are of most ordinary occurrence, and which require for their solution the usual geometrical constructions involved in tangent and secant planes and other surfaces to a surface defined by the projection of its horizontal curves. The cases which will here find their application may be arranged under two heads:

1.st The plan and command of a work being definitively decided upon, to ascertain the exact portions of the zones of danger from which any description of fire can be brough to bear upon its terre-pleins, and to defile them from it.

2.nd The plan of a work being definitively fixed, but its command only approximately within certain limits, to ascertain the easiest method of defiling the terre-pleins of the work by varying the command, or position of the interior crest, within the assigned limits.

134. *Prob. 1. Pl. VII. Fig. 2.* The command, or position of the interior crests of the faces of a work being fixed, to ascertain the dangerous points on the exterior, and to defile its terre-plein from these points.

Let a b, a c *be the projections of the given crests and the curves* (28,0), (29,0), *&c those of the natural surface*

Prolong outwards to c, *and* d, *the faces; construct the scales of declivity of the two lines* a e, a d; *and, from them, the scale of declivity* g f *of their plane. From the salient* a, *supposing an arc to be described with a radius of 1500 yards, the dangerous ground will be included between it and the two faces of the work. Now if the plane of the interior crests of which* g f *is the scale of declivity be indefinitely extended, and its intersection with the surface parallel to the natural surface and 6 feet above it be found, it is evident that the portion of this raised surface which lies below the plane may be disregarded, as no fire from it can have a plunge upon the interior of the work. But, from every point of the surface above the plane, a plunging fire can be brought to bear on the terre-plein. Having drawn the horizontals of the plane* g f, *and found their intersections with the corresponding horizontals of the raised surface, (which last will be given by adding 6 ft. or 2 yds to the references of the curves of the ground), of which* x y z *is the*

projection. That portion of the surface which lies above this curve will alone have a plunging fire upon the work, and will be the only portion for which defilement will be necessary.

Now as this intersection falls entirely within the angle **dae** of the faces prolonged, or within the limits of front fire, it is evident that the terre-pleins will require to be defiled only from direct fire.

To effect this let a plane be passed through the face **bad** of the work, and tangent to the raised surface above **xyz**. This plane will pass above all the dangerous ground, except at its point of contact with it; and, being extended back from the face within the work, it is clear, if the terre-plein of this face be so taken with respect to this plane that no point of it shall be less than 8 ft. below the plane, that then every point of the terre-plein will be screened from a plunging fire by the parapet of the face **ab**. Now if the same series of operations be gone through with for the face **cae**, then will its terre-plein be defiled in like manner; and thus the defilement of the whole work be completed for this case.

The tangent planes which satisfy the above condition are termed Planes of Direct Defilement, and they may be defined as planes which passed through

the interior crest of a parapet leave at least 6 ft. below them all the dangerous ground of front fire, and pass at least 8 ft above every point of the terre-plein behind the parapet.

The terre-pleins are usually parallel to their respective planes of direct defilement and 8 ft. below the But when the declivity of the plane of defilement exceeds 1/25 then the terre-plein, if it is to receive cannon, must be kept within this limit.

In the Fig. 2 the references are put down in yards. The tangent plane through **bad** is determined in the usual manner, by finding the horizontal (in this case (30,0), among all those drawn to the curves of the raised surface which makes the minimum angle with **bd**. The line **hi**, perpendicular to this horizontal, is the scale of declivity of this plane; and the point **p**, that of contact. The line **kl** is, in like manner, the scale of declivity of the other plane, and **o** its point of contact.

135. It might happen, from the steepness of the terre-pleins, that the re-entering, or gutter, formed at their intersection would be inconvenient, and it would therefore be desirable to have this portion raised, when it can be done without exposure to a plunging fire. This in most cases may be effected

in this way. It will be seen, from an inspection of the Fig: 2., that the points o, and p are the only ones from which the enemy's fire passes exactly at 8 ft above all the points of the restrected terre-pleins determined by the tangent planes; and that if, from these points, lines of fire oar, and pas, be drawn, every other line of fire through a, from the ground in the angle pao, will pass more than 8 ft above the portion of the terre pleins embraced in the angle sar, since the ground within the exterior angle lies below the tangent planes. If then a be taken as the vertex of a cone, the elements of which are tangent to the raised surface within the angle pao, and if these elements be prolonged within the work, their prolongation will form a cone of lines of fire which will pass more than 8 ft above the terre pleins. If these last therefore be connected by a surface parallel to this cone, and 8 ft below it, this surface may be taken as the portion of the terre-plein which connecting the two plane portions will remedy the inconvenience pointed out.

136. *Prob. 2. Fig: 3.* The data being the same as in the preceding case, and the work being exposed to both direct and reverse views, to cover its interior from these views.

Suppose the plane of the interior crest of the

faces extended within the limits, and its intersection with the dangerous ground determined as in the preceding case; and let **xyz**, **mno**, and **pqr** be the curves of this intersection.

The face **ab** will be exposed to direct fire alone from the ground above the two curves **xyz**, and **mno**; and to reverse fire from that above the curve **pqr**. In like manner, the face **ac** will be exposed to direct fire from **xyz** and **pqr**, and to reverse fire from **mno**.

The defilement of each face from the direct fire will be effected precisely in the same way as in the preceding **Prob**. The lines **hi** and **kl** are the scales of declivity of the planes of direct defilement of the faces respectively.

For the reverse defilement, a plane is passed through **ab**, tangent to the surface above **pqr**; and one through **ac**, tangent to the surface above **mno**; and their line of intersection **aa'** found. The line **uv** is the scale of declivity of one of these planes, termed a Plane of Reverse Defilement; and **st** that of the other.

Now if a traverse is so placed that its crest shall occupy the position of the line **aa'**, it will cover all between it and the two faces, as high as the interior crests, from the reverse fire on each side. But as it is desirable to have the troops when on the banquette

screened from this fire, the crest of the traverse should be raised from 18 inches to 2 feet above the line a a' to effect this.

The traverse should extend so far towards the gorge of the work that the entire line of each face shall be covered by it. To determine its length with this condition, lines are drawn, from the extreme point b, and c of the faces, tangent to the curves mno, and pqr, and their points of intersection with a·a' marked; the one that falls farthest from the salient will evidently give the required length.

If the line a a' should fall so near either of the faces that the traverse, if placed along it, would incommod the service of that part of the work, it will be best to place its crest in the vertical plane a a'' of the capital of the work When so placed the intersection of this vertical plane with each of the planes of reverse defilement must be found, and the crest of the traverse be taken 18 inches above the one that lies highest.

137 The position of the crest of the traverse, as determined by either of the preceding methods, will be in a vertical plane passing through the salient a of the work. From the thickness and slopes which traverses usually receive, they would ordinarily, if placed in this position take up all the interior space within the salient, and

leave no room there for dispositions either for artillery, or musketry. To prevent this a break is made in the direction of the crest at some point on the vertical plane through the salient, from which it is directed on a point of either of the faces, so far from the salient that sufficient room will be left for the object in view. In the Fig 1 which illustrates this arrangement, the traverse is withdrawn far enough from the salient to leave room for a barbette battery for several guns.

The face upon which the traverse is directed will be determined by the condition of covering both faces in the most effective manner by the position taken for the traverse.

138. The cross sections of traverses for permanent works is similar to those used in field works. The top of the traverse receives a slight slope each way from the crest to the sides. The thickness at top is from 12 to 20 ft to render it shot proof. The sides take the natural slope from the top, either to their intersections with the planes of direct defilement, or to the terre-plein. If to gain interior space, these slopes are terminated at the planes of direct defilement then the portions of the traverse below these planes are made more steep and the earth supported by retaining walls. The top of the traverse, where it joins

out above this slope, upon which the side slopes fall; its extremity terminates in the plane of the exterior slope extended above the exterior crest.

139. Traverses may be arranged for bomb-proof shelters and musketry defence by throwing a bomb-proof arch between the side retaining walls, and piercing the wall bearing on the portion of the terre-plein which will first fall into the enemy's power with loop-holes.

140. When, from any circumstance, a single traverse cannot be used for reverse defilement, resort must be had to several, which should be so combined that no line of fire can penetrate between their extremities to attain any point which they should cover. The examples of like combinations, given in the Front, will readily suggest the manner of making others; of which farther illustrations will be found in the following case.

141. Where a demi-lune is arranged with a redoubt, a traverse placed in its salient cannot be extended farthe back than the counterscarp of the redoubt, and an open space therefore will be left at the ditch, through which a reverse fire would attain that portion of either face which is not covered either by the traverse in the salient, or by the parapet of the redoubt. To cover the part thus exposed, it will be necessary to place one or more

traverses which, in combination with the one in the salient and the parapet of the redoubt, shall subserve this end

To simply the case, let the face a c (Pl. VII. Fig. 5.) be the one exposed, and let the point x be one the fire of which is most dangerous. Having in the first place arranged the traverse t, as in the last example, and drawn the two lines of fire x b, and x d, from the point x, through the extremity of the traverse, and the top of the parapet of the redoubt at the salient, the length b d of the face intercepted between these lines will be the part to be covered. If a second traverse t' be placed across the terre-plein of the other face of the demi-lune, and in a position such that one of its ends shall rest on x b, and the other on x d, it will evidently cover the portion b d.

142. In selecting the positions of several combined traverses, attention must be given to avoid those where, if one be placed, the enemy would find shelter behind it from the fire in the rear. In the example just taken, the slope of t, towards the salient, should be swept by the fire from the rear through the redoubt; and the like slope of t' should be swept by a portion of the redoubt face near its salient; and neither so fall as to have the space behind it masked from fire by the one to its rear.

143. Traverses usually present not only the easiest solution of all problems of reverse and enfilading defilement, but affording the means of rendering the command independent of the fire from without, they enable the engineer to regulate this element solely with a view to the effect which he desires to attain by his own fire. From the space required for their erection, traverses may, as in the cases of narrow terre-pleins, like those of the covered ways, and of the demi-lune with a redoubt, be inconvenient, both from embarrassing the communications, and from taking up ground that may be wanted for batteries.

144. **Prob. 3.** The plan of a bastion being definitively fixed, and one point of its command approximately, to defile the work in the most advantageous manner, by shifting the position of its interior crest within certain limits.

Let Fig. 6 be the plan of the work, and a the salient, the command of which can be varied within certain limits, without impairing any of the other conditions; and let the dangerous ground be embraced within the arc m n, at 1500 yds from a, and the lines a u, and a v, supposed drawn from a through covering masses on the right and left of the work.

The front limits of defilement in this case

are embraced within the sector man ; and the lateral within the other two mau, and nav. Now the most f case of defilement here will be that, where a plane, ci ing a taken within its extreme positions, shall pass a all the exterior ground, and give such a command t interior crest throughout, when held in it, as sha fy the other conditions of defence. To ascertain the tence of such a plane, let a be taken as the verte a cone which envelopes all the dangerous ground, plane tangent to this cone will satisfy the conditi defilement, and it will therefore only be necessary whether any one of these planes of defilement wil fy the other of giving the points b,c,d, and e a su command. If no such plane can be obtained, the m favorable case will be to find one that shall satisfy requisite conditions of command, and intersect the only within the front limits. In this case it is clea the position of this plane, if the interior crests are in it, that the interior of the work will be expos to the direct fire from that portion of the ground u lies above the plane

Let x y z be the curve of intersection of th with the ground, found in the usual way. Through t faces a b, and a d, let planes of direct defilement be pa the terre pleins of the faces being held parallel to them

be covered by their respective parapets from all plunging fire. But, in order that the planes of defilement of the faces shall also defile the flanks, it is necessary that each flank be placed in the plane of defilement of the adjacent face, and its terre-plein in that of the terre-plein of the face. Now, in giving the interior crests of the flanks these new positions, they will lie below the plane that contains the curve **xyz**, and in which the interior crests of the faces lie. This being the case it may happen that the parapet of one of the flanks will not cover the opposite face from reverse fire, coming from the lateral limits opposite the flank. In this contingency, it will be necessary, in order to cover the face, to place the flank in the plane of the curve **xyz**, as this plane defiles from the lateral limits; but, in doing this, the flank **de**, for example, will be exposed, in its turn, to the ground above **xyz**; and to cover it the only remedy is to erect a traverse, at some suitable point, which shall intercept all this dangerous fire. The least inconvenient position for the traverse will usually be at the shoulder angle. From this point, it must extend so far back as to intercept all fire from above **xyz**, both on the terre-pleins of the flank and curtain where they unite, and be high enough to screen the troops on the banquette.

If the defilement cannot be effected by either

of these processes, there remains no other means than, first definitively fixed the command, to divide the s by a traverse, either along its capital, or some other venient direction, and, having given it a suitab height, to cover each portion from direct fire by the u method.

145. The foregoing problems embrace in their all of the more ordinary cases of defilement, and gest the route to be followed in treating others. In cases of the defilement of combined works, like the ceinte and its out-works, &c. it must be borne in that the advanced works, which from their positio must first fall into the enemy's power, become th a portion of the dangerous ground for the works retired, and which must also be held after the fall others. The retired works under such circumstances be defiled from the advanced; their planes of de ment being made to pass from 3 ft. to 4.5 ft above portion of the advanced work on which it is presu the enemy may make a lodgment, and which, f its position, may be regarded as the most danger to the retired work. It is according to this rule the redoubt of the re-entering place of arms is de from the parapets of the two adjacent demi-lu its plane of defilement extended outwards passing

3 feet above the salients of these works. The tenaille, in like manner, is defiled from the upper terre-plein of the demi-lune redoubt, as the tenaille must be held after the enemy has established himself on this terre-plein. For like reasons the more retired portions of the covered-ways are defiled from the enemy's lodgments on the glacis of the demi-lune salient place of arms.

146. Where a work has considerable command, and is open at the gorge, like the cavalier retrenchments, for example, and the works in its rear do not mask its interior from reverse fire, it may be necessary to place the traverse, termed a parados, across its terre-plein at the gorge, giving it sufficient height to subserve the end in view.

147. The methods of defilement here laid down are those now followed by engineers. They unite mathematical exactness in results with great simplicity of detail; and render the defilement altogether secondary to the other conditions of defence upon which the plan and command are made essentially to depend. Before they were adopted the results of the method then followed were in most respects, like those obtained in the practical operations for defiling field works. A line, the position of which was determined by a series of trials, having for their object to obtain the most satisfactory results both as to the economy of the requisite embankments and the best disposition of

command of the various parts, at or in rear of the gorge of the work to be defiled, this position coinciding with the natural surface, or being above, or beneath it, as the case required. Through this line a plane was passed tangent to the dangerous ground. This plane termed, as in field defilement, a Rampant Plane, was taken as the artificial site of the work, in reference to which the relative command of all the parts was arranged as upon a horizontal site. Or, in other words, the result was nearly the same as if the works had been arranged on a horizontal site, and then the whole combination turned around some fixed line of this site until it was brought into the position of the required rampant plane. The defects of this method are evident at a glance. It preserves the relations of defence of the various works the same as in a horizontal site; but it, to a great extent, leaves out of consideration the bearing of the command on the exterior ground, and, in many cases, may lead to excessive excavations and embankments which the methods now followed enable the engineer for the most part to avoid.

Accessory Defences.

148. Under this head is classified a variety of defensive arrangements usually regarded of a secondary character, but which in some cases constitute the main and only means of defence. They are either such defensive works as may be requisite for strengthening the principal work on points where it is weakest from some irremediable defect in its plan &c, or from some peculiarities in the natural features of the site by which points although within the range of the fire of the principal work cannot be attained by this fire; or are dispositions made for prolonging the defence by taking advantage of such local features as water, rock, marshes &c as can be converted into passive obstacles to the assailant's approaches. Of this description of works are Mines; Scarp and Counterscarp – Galleries; Casemates for cannon; Additional Outworks; Detached-works; Forts; Dikes and Sluices for water; &c, &c.

Mines.

149. The subject of mines admits of a division into five parts.

1. The Nomenclature.
2. The results of Experiments, and the Theory founded on them

3. The manner of using mines in the Attack and Defence.
4. The conditions to which mines should be subjected in th arrangement and uses.
5. The construction or details of the practical operations.

To these may be added a sixth part comprisi the uses of mines in temporary works.

150. **Nomenclature.** The term Mine is applies both to the underground excavations charged with powde for the purpose of producing an external explosion, and to the communications which lead to these excavations.

The excavation in which the charge of powd is lodged is termed the Chamber. The pit formed by the explosion is termed the crater.

The form of the crater in ordinary soils has never been exactly ascertained. The only use of exact determination of this form would be to calculate precisely the quantity of earth thrown from the crater, and by the means to proportion the charge to the effect to be produced Different figures have been assigned by engineers to this solid; some assuming it to be a cone of which the centre of the powder was taken as the vertex; others a parabol of which the center of the powder was the focus. To affo a uniform and simple rule for calculating the volume of the crater, the solid (Fig. A) is assumed to be a trun cated cone, the radius c d, of the lower circle being one

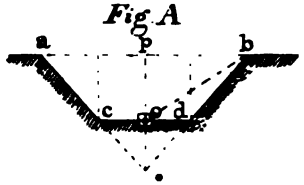

Fig A

half the radius a b, of the upper circle. The radius p b, of the upper circle is termed the crater radius. The line o p drawn from the center of the powder perpendicular to the surface where the explosion takes place the line of least resistance. The line o b drawn from the same center to any point in the circumference of the upper circle the radius of explosion.

The term common mine is applied to a crater when its radius is equal to the line of least resistance. When the crater radius is greater than the line of least resistance the terms overcharged mine, and globe of compression are used. When the crater radius is less than the line of least resistance the mine is termed undercharged. A small mine with a line of least resistance not greater than 9 feet, which is formed by sinking a shaft from the surface of the ground, is termed a fougasse. The term camouflet is applied to small mines used to suffocate the enemy's miner without producing an external explosion.

The underground communications required for the service of mines are termed galleries. The galleries are either arched communications of masonry, or else a frame work and sheeting of timber. The principal gallery immediately behind the counterscarp

wall, is termed the counterscarp or magistral gallery. An enveloping gallery is one parallel to the counterscarp gallery, and at some 30 or 40 yards in advance of it The galleries leading outwards from the counterscarp gallery are termed listening galleries. The galleries which connect several listening galleries are termed transversal or cross galleries. Galleries receive also particular names from their size as

The Great or grand galleries, which are 6 feet high and 6 ft. wide

Common galleries	6	3
Half galleries	4½	3
Branches	3½	2½
Small branches	2½	2

151. Experiments. But little advance by experiment has been made in the subject of mines; owing to the time, labor, and expense, which a prosecution of the subject demands; and the practice has therefore undergone but slight changes since the earliest introduction of this means of attack and defence. The following facts, drawn from observation, comprise almost all that is at present known on the subject.

1. In solid rock an explosion causes the rock to split in various directions, and if the charge is heavy will break it into small fragments which are frequently

2 In sand the gazes seem to penetrate between the grains, producing a crater of a regular form, the radius of the upper circle of which is generally small in comparison with the depth.

3. In ordinary tenacious soils, the first effect of the explosion is to produce a rumbling noise and a sensible trembling of the earth around the mine to a considerable distance; the ground directly over the mine is next observed to rise in the form of a spherical segment, which increases perceptibly until the smoke commences to issue forth around its base; the explosion outwards follows immediately on this last change, the earth mingled with smoke and flame, being thrown upwards and outwards, so as to assume a form something like a water spout; part of earth falling back into the crater, and a part without forming a ridge around its mouth.

The two most remarkable features of the explosion are its internal and external effects; the first producing the crater; the second so disturbing the earth for a considerable distance around the crater, as to fill up cavities, destroy galleries &c, within the sphere of its action; these effects extending farther in a lateral than in a downward direction.

The charges and their effects do not follow the same ratio, the last increasing less rapidly than

the first. Experiment has shown that the charges m
even be increased, one or two pounds per 4 cubic ya
without increasing the crater radius, the only effect o
increase of charge being to throw more of the earth
of the crater.

From experiments made on common min
with a line of least resistance not exceeding 15 feet, it
been ascertained that the tenacity of the earth is com
pletely destroyed, around the crater, to a distance e
to the line of least resistance, and that empty gall
are broken in at a distance of one and a half the
line.

In homogeneous soils the resistance due t
tenacity of the soil is nearly proportional to the mass.

It was for a long time supposed by miners
a crater could not be formed with a diameter greater
than twice the line of least resistance with any charg
the experiments of Belidor, have shown that, by succ
augmentations of the charge, the crater radius may
increased to 6 times this line, but not much beyond
that within this limit the ratio of the diameters of
craters is nearly that of the square root of the charg
and that galleries can be destroyed by such mines a
distances of 4 times their line of least resistance.

152. Theory. The physico-mathematical theory of

is still very imperfect, owing to the impracticability of ascertaining the exact effects of the explosion of powder in a medium which is seldom homogeneous, and the resistance of which, arising from its tenacity, compressibility &c. to the expansion of the gazes, can only be arrived at by a wide range of experiments made with minute care.

From the want of these elementary data the formulæ at present in use, to determine the charges for different media, are necessarily empirical, and their results are to be relied on only within the limits in which they coincide with experiments. For most cases in practice, these approximations are near enough, and valuable as the only guides that the miner has to refer to.

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c,c′ the charges,

r,r′ the radii of the craters,

l,l′ the lines of least resistance,

d,d′ the weight of the unit of volume of the two soils,

n, n' the constants which multiplied into the weights will express the tenacities.

h, h' the heights of the atmospheric columns reduced to the same densities as the soils.

Whatever may be the form of the crater its volume can be expressed in terms of the surface of the circle and some fractional part of the line of least resistance so that if we represent it by $\frac{1}{m} l$ and $\frac{1}{m'} l'$ this fractional part of the line of least resistance in the two cases, we have for the expression of the two volumes

$$\pi r^2 \times \frac{l}{m}, \text{ and } \pi r'^2 \times \frac{l}{m'};$$

and for their respective weights

$$\frac{\pi r^2 l}{m} \times d, \text{ and } \frac{\pi r'^2 l}{m'} \times d';$$

to express the tenacities we have

$$\frac{\pi r^2 l d}{m} \times n \text{ and } \frac{\pi r'^2 l' d'}{m'} \times n';$$

and for the weights corresponding to the atmospheric resistance

$$\pi r^2 h d, \text{ and } \pi r'^2 h' d'.$$

From these expressions we derive the equations

$$c : c' :: \frac{r^2 d}{m} \left(n + 1 \right) l + m h \Big) : \frac{r'^2 d'}{m'} \left((n+1) l + m h' \right)$$

For the same soil as $m = m'$, $n = n'$, $d = d'$, and $h = h'$, the proportion becomes

$$c : c' :: r^2 \left(l + \frac{m}{n+1} h \right) . r'^2 \left(l + \frac{m'}{n+1} h \right)$$

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experiment. the crater formed by any known charge has been found, consequently the quantities n and h are also known. of the first nothing definite is known but that it varies with the kind of soil. the second has been assumed equal to 11 feet. This want of definiteness in the value of these quantities has led to omitting them in the proportion. when used for practical purposes, in which case it takes the following form.

$$c : c' :: l r^2 . : l' r'^2 \qquad . (4.)$$

This is termed the Miners Roule, as it is used for calculating tables of charges for different soils; and its results do not suffer materially from those of experiments

Making $l - l'$ the proportion becomes

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a proportion also suffering but little from the results obtained within the ordinary limits of practice, when the lines of least resistance are the same for different charges.

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another form of the Miners Roule; and the one used in calculating the tables of charges for similar mines.

The manner in which this rule is applied to calculate the charges of common mines is as follows; the quantity of powder q, in pounds, required to throw up one cubic yard of any species of soil, is found by experiment; As the solid contents of a truncated cone like Fig. A. is equal to $\frac{11}{6}$ l³, l being the line of least resistance, the volume of the crater whose line of least resistance is one yard will be represented by $\frac{11}{6} \times (1^3)$ or $\frac{11}{6}$; thus volume multiplied by q will give the charge in pounds for this crater, but from the proportion $c : c' :: l^3 : l'^3$ there obtains

$$c : \tfrac{11}{6}\, q :: l^3 : 1^3, \text{ or } c = \tfrac{11}{6}\, q\, l^3,$$

for the charge for a crater whose line of least resistance is l is to find the charge for a given line of least resistance, cube the line, expressed in yards, take $\frac{11}{6}$ of the result and multiply it by the number of pounds required to throw out a cubic yard of the soil in question.

The following Table expresses the values of q

Light sandy earth	1 lb. 13 l
Hard sand	2 . 00
Common earth	1 . 10
Wet sand	2 . 2
Earth mixed with pebbles	2 . 8
Clay mixed with loam	2 . 1
Rock	3 . 1

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mines resort must be had to some other to find the charges for over charged and undercharged mines. The formulas in most general use for these cases are those of Lebrun a French engineer; which although not based on any satisfactory hypothesis nevertheless coincide nearly in their results with those obtained by experiments within ordinary limits. The hypothesis assumed to obtain these formula is as follows. Suppose two craters, formed by two different charges C, and C', with the same line of least resistance, one giving a crater radius r equal to the line of least resistance, the other a crater radius R greater, the difference of the radii being R−r; next suppose the charge C' to belong to a common mine of which the crater radius is r', r'-r being the difference of the radii of two craters of the common mines of which the charges are C and C'; then the ratio of the two differences here expressed, arising from the same increase C' of the charge C, will be constant under all circumstances of variation of soil, and of the lines of least resistance. Calling K this constant ratio, there obtains

$$\frac{R-r}{r'-r} = K;$$

assuming $R = n\,r$, this formula becomes

$$\frac{r(n-1)}{r'-r} = K,$$

or $$\frac{r'}{r} = \frac{1}{K} \times (n-1) + 1,$$

but as r' and r belong to similar craters, the Miner's Rule gives $\frac{C}{C'} = \frac{r^3}{r'^3}$; from this there obtains,

$$c' = c \left\{ \frac{1}{K} (n-1) + 1 \right\}^3.$$

The quantity K which enters into this expression must ascertained by experiment, as indicated by the process followed in obtaining the formula. From a comparis of a number of experiments the value of K gives

$$c' = c \left\{ 0,91\ n + 0,09 \right\}^3;$$

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$$\frac{r - R}{r - r'} = K,$$

and hence $c' = c \left\{ 1 - \frac{1}{K} (1-n) \right\}^3 \ldots (X)$

The constant K in this case, is determined from a result experiment; that if a certain charge of powder forms a c mon crater, with a line of least resistance l, the same c will not produce any external effect when the line of lea resistance is increased to 1¾ l, or 7/4 l; and reciprocally a charge produces no external effect with a line of least re tance l, the same charge will form a common mine wi a line of least resistance 4/7 l. If then the charge c', by s position, does not produce any external effect under the of least resistance l it will produce a common mine und a line of least resistance 4/7 l; from this by the Steiners there obtains

$$c' : : c : : (4/7\, l)^3 : l^3$$

or

$$c' = c \left(4/7 \right)^3$$

Now substituting this value of c' in Eq (X) and making n=0 its corresponding value for this of c'; there obtains $\frac{1}{K} = \frac{1}{7}$, which result substituted in the same Eq (X) it then becomes

$$c' = c\left[1 - \tfrac{3}{7}\left(1 - n\right)\right]^3;$$

$$\text{hence} \quad c' = c\left(\tfrac{3n+4}{7}\right)^3,$$

which is the formula for undercharged mines.

158. **Employment of Mines in Attack and Defence.** Mines were at first employed only by the besiegers for the purpose of effecting breaches in the revetment walls of fortifications; subsequently they were used by the besieged to destroy the trenches and other works of the besiegers, and to anticipate his miners in their operations, from which uses they received the name of counter mines.

159. A system of counter-mines consists usually of a combination of main and secondary galleries, of various sized branches, and of mine chambers, arranged with a view to anticipate the enemy at every point on which he may approach the defences for the purpose of destroying them by his mines, and to break up the ground over which he must run his trenches in his attacks above ground.

160. The main galleries are placed, as has already been stated, either directly against the counterscarp wall, or at some yards in rear of it, as may be most suitable for the object in view; and they serve as depots for the

tools and materials required for the mining service, and are also the point from which the galleries leading outwards start.

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162. The mines used in the defence are generally common mines with a line of least resistance seldom greater tan 15 feet. As the object sought by the besieged is simply to destroy the trenches, batteries &c., these mines are the most suitable for this purpose, they require little powder, and their effects will not be felt by the galleries &c of the besieged. If the besiegers resort to mining in the attack, the besiegers await his operations, working at the extremities of the listening galleries for

approach of his miner, who can be heard at work at distances of 12 or 15 yards; the besieged miner then pushes forward a short branch from the listening gallery towards the enemy's, establishes a camouflet at the end of the branch and explodes it so soon as he judges it will produce the desired effect; which is to break through into the enemy's gallery and stifle the miner at his work.

163. The course pursued in the attack consists in establishing globes of compression with crater radii from 4 to 6 times the lines of least resistance; these mines are arranged by first sinking a vertical pit, termed a shaft, sufficiently low to reach the lowest galleries of the besieged; and from the bottom of this shaft running out a short branch at the extremity of which a chamber is placed to receive the charge.

164. In order that the charge shall produce the desired effect the branch leading to the chamber must be filled with sand bags and other materials compactly laid to prevent the explosion taking place in a wrong direction this operation is termed tamping. From experiments made by Mouzé a French engineer, it appears that without tamping, by doubling the charge, the same effect may be produced as that by the usual charge with tamping; that, by increasing the charge ¼, the usual tamping may be decreased ⅓, and that, by

the first Experiment has shown that the charges may even be increased one or two pounds per cubic yards, without increasing the crater radius. the only effect of this increase of charge being to throw more of the earth clear of the crater

From experiments made in common mines with a line of least resistance not exceeding 15 feet, it has been ascertained that the tenacity of the earth is completely destroyed around the crater to a distance equal to the line of least resistance, and that empty galleries are broken in at a distance of one and a half the same line.

In homogeneous soils the resistance due to the tenacity of the soil is nearly proportional to the mass.

It was for a long time supposed by miners that a crater could not be formed with a diameter greater than twice the line of least resistance with any charge; the experiments of Belidor, have shown that, by successive augmentations of the charge, the crater radius may be increased to 3 times this line. but not much beyond; that within this limit the ratio of the diameters of the craters is nearly that of the square root of the charges; and that galleries can be destroyed by such mines at distances of 4 times their line of least resistance.

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but as r' and r belong to similar craters, the Miner's Rule gives $\frac{c}{c'} = \frac{r^3}{r'^3}$; from this there obtains,

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The quantity K which enters into this expression must be ascertained by experiment, as indicated by the process followed in obtaining the formula. From a comparison of a number of experiments the value of K gives

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$$c = c \left\{ 1 - \tfrac{3}{7} \left(1 - n \right) \right\}^3;$$

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158. **Employment of Mines in Attack and Defence.** Mines were at first employed only by the besiegers for the purpose of effecting breaches in the revetment walls of fortifications; subsequently they were used by the besieged to destroy the trenches and other works of the besiegers, and to anticipate his miners in their operations, from which uses they received the name of counter mines.

159. A system of counter-mines consists usually of a combination of main, and secondary galleries, of various sized branches, and of mine chambers, arranged with a view to anticipate the enemy at every point on which he may approach the defences for the purpose of destroying them by his mines, and to break up the ground over which he must run his trenches in his attacks above ground.

160. The main galleries are placed, as has already been stated, either directly against the counterscarp wall, or at some yards in rear of it, as may be most suitable for the object in view; and they serve as depots for the

tools and materials required for the mining service, and are also the point from which the galleries leading outwards start.

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164. In order that the charge shall produce the desired effect the branch leading to the chamber must be filled with sand bags and other materials compactly laid to prevent the explosion taking place in a wrong direction this operation is termed tamping. From experiments made by Mauzé a French engineer, it appears that without tamping, by doubling the charge, the same effect may be produced as that by the usual charge with tamping; that, by increasing the charge ¼, the usual tamping may be decreased ⅓. and that, by

increasing the charge ½, about ⅔ of the tamping may be dispensed with. These facts are of importance in the at for a great part of the time consumed in establishing a mine is required for the tamping.

165. The following method of attack against a syst of counter mines has been proposed by Gillot, another F engineer, based upon the experiments of Abougé. Afte the 3d parallel is finished, Gillot proposed to form a 4 parallel; then to sink shafts in it about 6 yards apart, and at the bottom of these shafts to place globes of com- pression, without tamping, and explode them at one The effect of this explosion he supposes will be to des the galleries of the besieged. As soon as this explosion ta place, he proposes next to carry the covered way by s and by globes of compression, established at the botto of shafts sunk in its terre plein, to destroy the entrance the galleries, and thus deprive the besieged of the use of his entire system.

166. Conditions to be satisfied in arrang a System of Mines. As the galleries of a system mines serve the purpose of underground communica they should be subjected to the same conditions as c communications. A condition of primary importa is, that no combination shall be made which ma compromise the safety of the enceinte. To this end

gallery under the glacis should lead to the interior of the enceinte; for should the enemy get possession of such a gallery he might either penetrate into the work or else barricade the gallery and hold possession of it long enough to blow up the works under which it leads.

167. The galleries should not offer any facilities to the besiegers for carrying on their works. Those galleries therefore which, débouching in the ditches, might serve the besiegers for their descent of the ditch; also a continued counterscarp gallery which may not only facilitate the descent of the ditch of the besiegers, but also, when in their possession, give them that of the whole system, and besides serve to protect their passage of the ditch, and to prevent sorties in it, should be rejected. A gallery behind a portion of the counterscarp not favorable to the enemy's works, is very useful as a depot for the implements of the miners, and also as a communication.

168. A permanent system of mines should not be used either for works that can be carried by storm, or for covered ways in a similar state; for the reason that the besiegers might easily get possession of the system before it could be brought into play.

169. The débouche of a system in the ditches must be revetted,* to offer a sufficient obstacle to prevent the

enemy from getting possession of the system by surprise hence a revetted counterscarp is a necessary condition in the establishment of the system.

170. The galleries should not be run out to any considerable distance beyond the covered ways, both on account of procuring a good circulation of air, and because very advanced galleries are easily destroyed by the besiegers. The distance to which the galleries may extend should be so much the less as the ground above them is well protected by the collateral works.

171. The soil must be suitable for the establishment of a system; wet marshy ground, shifting sand, and hard rock present almost insuperable obstacles; whereas a dry firm soil, soft rock, or ordinary earth under a thin superstratum of hard rock are very favorable circumstances. If the sub-soil is wet, but presents a firm and dry superstratum 12 feet thick above the level at which the water collects mines may still be placed with advantage.

172. Besides the above general conditions there are certain special ones to be attended to in arranging the galleries and chambers.

The galleries should be placed as far below the surface as practicable, to withdraw them from the effect of the globes of compression of the besiegers. To drain the galleries they should have a slight inclination about $\frac{1}{20}$

towards the ditches, or if the ground descends towards a hollow the inclination may be given in that direction.

173. The chambers, on the contrary, should be near the surface; by this arrangement the powder is economised, and all danger to the galleries from the explosion avoided, whilst the object of the mines, which is to destroy the enemy's works, can be as fully attained by small mines as large ones.

174. The galleries should not be placed nearer to each other than twice the line of least resistance of the heaviest charged mines, and not much less than four times the line of least resistance of the smallest charges. This arrangement will admit of a combination of mines in two tiers, the line of least resistance of the lower being double that of the upper, the chambers of which may be so arranged that the explosions of one tier shall not affect either the galleries or the mines of the other. Twice the line of least resistance of the largest mines is the least distance that can be allowed between the galleries in order that the mines of the lowest tier, which, being placed near one gallery, must destroy a part of it, shall not injure those parallel to it. By placing the galleries at this least distance apart the branches for the service of the upper tier will be as short as possible, effecting thus a saving of time and labor, and from the same cause

the galleries on any one point being as many as can be placed, there will be the advantage that some one of the galleries will be serviceable should others be injured by explosions.

175. The galleries and branches for the service of different groups of mines should, be independent of each other, so that there may be no confusion in the service, and that no group may be rendered unserviceable by the destruction of the communications to another. The same principle should be attended to in combining the different groups of mine chambers.

176. The galleries and branches should never present their flanks, or sides to the globes of compression of the besiegers. This rule leads to the rejection of enveloping galleries.

177. The systems of counter mines proposed by most writers on this branch of the defence are generally of too complicated a character to admit of being executed at a reasonable cost, and they require for their service not only a large amount of powder but also a great number of miners.

The following arrangement, based on the general conditions just laid down, has been proposed, to meet in a simple and satisfactory manner the requisites of a subterranean defence.

Parallel to the capital of the demilune four listening galleries are run out to a distance from 50 to 80 yards beyond the saluent of the covered way. The interval between these galleries being twice the line of least resistance of the heaviest charged mines. If we take this line at 7 yards, or 21 feet, which is about the greatest for common mines, the interval of the galleries will be 15 yards. The dimensions of the listening galleries for about the first 20 yards may be those of a grand gallery, and the remaining part may be a common gallery. These galleries will depart from a transversal grand gallery about 6 yards from the demi-lune counterscarp which will serve as a communication between them, and also as a depot. Other transversals of the size of half galleries, or branches, will be made at different intervals for the purpose of ventilation. This group of galleries will have their outlet into the demi-lune ditch through two galleries, one leading from each extremity of the transversal grand gallery. To flank this group other listening galleries will extend obliquely outwards from the two outside parallel galleries. To serve the mines of this group, a series of ascending branches will lead from the galleries to chambers, placed midway between the galleries, having a line of least resistance of 4 yards. This will place these chambers at about 8 yards from the two adjacent galleries. Smaller branches may lead

if necessary, from these last branches to other groups
chambers having a line of least resistance of 2 or 3
A series of chambers with lines of least resistance of
will be established in juxtaposition with each list
gallery. From this arrangement it will be readily seen
ground over the galleries can be entirely broken up
that the successive explosions of the mines of one
will destroy the branches and galleries which lead to
without injuring those of other groups. The object
disposition is to blow up by repeated explosions t
ground over which the enemy must approach up
the demi lune salient place of arms.

178. For the defence of the other portions of
glacis of the demi-lune covered way a countersca
gallery of the dimensions of a grand gallery is pl
between the two traverses next to the reentering pla
arms; a listening gallery extends from one extrem
of this gallery in an oblique direction outwards, a
nearly parallel to the long branch of the covered
crest between the two traverses, to within 20 yards of
foregoing arrangement. Other listening galleries, pla
15 yards apart, run out from the main one, about
to menace every point of the glacis that can be occ
by the besiegers works. The groups of mines for thes
leries may be arranged like those of the combina

in advance of the demi lune salient place of arms. The counterscarp gallery should have two outlets in the demi-lune ditch; but as these might compromise the safety of the whole arrangement should be besiegers attack the covered way by storm, they must be walled up when the 3d parallel is completed, and the communication with the galleries then kept up by a gallery leading to the main ditch. To supply the main listening gallery of this group with air, a branch should lead to it from a point of the demi-lune counterscarp under the traverse next to the one of the salient place of arms.

179. Groups of galleries and mines similar to the one in front of the demi-lune salient place of arms may be arranged for the defence of the bastion salient place of arms. And a gallery leading from the counterscarp of the main ditch may be made for the service of a group for the defence of the glacis of the reentering place of arms.

180. To defend the breaches made in the demi-lune and its redoubt, a gallery may be made under the ditch of the redoubt having its outlet in the main ditch; this gallery may divide into two branches one leading under the demi-lune breach, the other under that of the redoubt. Ascending branches may

be made from the gallery leading to the demi-
breach for the service of a group of mines to b
up the demi-lune terre-plein.

181. Finally if the bastions are arrangea
interior retrenchments a disposition similar
one made for the defence of the demi-lune m
be made for the defence of the bastion breach.

182. Practical Details of Construction G
of mines may be either permanent or temporar
former are constructed of masonry and usually
the same time with the other constructions of
ry of the work, the latter are made of frame
covered in by plank, and are prepared but a
period before they are required for use.

183. The frames of temporary galleries co
of four pieces; two uprights termed stranchions
two horizontal pieces, the one at top termed a c
and the bottom piece a ground sill, **Pl.VIII. Fig 1**
shows the connection between the parts of the fra

The plank or boards, which cover in
frames is termed sheeting. The top sheeting of th
usually consists of boards from 3 feet 6 inches t
in length, from 7 to 12 inches in width, and f
1 to 1½ inches thick. The side sheeting may h
the same length and breadth but need not be

than from 3/4 to 1 inch. To set the frames up and retain them in their places slips of plank, termed battens are used, which are about 2½ inches wide and 1 inch thick.

The frames may be either of well seasoned oak, or pine, the latter is preferable as lightest. The parts of each frame receive the dimensions in the annexed table.

	ground Sill	Stanchions	Cap Sill
Great gallery	6"×4½	6"×6"	7"×6
Common gallery	5×4	5×5	6×5
Half gallery	4½×3½	4½×4½	5×4½
Branches	3½×3	3½×3½	4½×3½
Small Branches	3×3	3×3	4×3

184. Shafts Pl.VII. Figs.3.4.5. A shaft is a vertical pit, lined with sheeting on the outside of frames which are placed horizontally, and at suitable intervals apart.

185. The cross sections of shafts are either squares, or rectangles; the dimensions of the sides of the section depending on the object of the shaft. When this is for driving a gallery from the bottom of the shaft, the dimensions of the shaft frames in the clear must be at least equal to that of the gallery from out to out of its sheeting. A shaft, sunk for establishing a mine chamber simply, should usually be of the least

dimensions, which, to allow the miner to work with facility, must not be less than 3 ft. by 2 ft. in the clear

186. Two kinds of frames are usually requisite in sinking shafts a Top Frame, Fig. 1. formed of four pieces, halved to fit each other, which, when put together, have the same dimensions in the clear as the shaft; each piece projecting beyond the sides, or having an over-length of 1½ to 2 ft. The other is termed a Side Frame, Fig. 2 and also consists of four pieces of smaller scantling than the top frame, halved at the ends to fit; its dimensions in the clear being the same as the other.

187. In very loose soil it may be necessary to use a temporary frame, o. Fig. 1, termed an Auxiliary F... This is somewhat larger in the clear than the prec... Its uses will be explained farther on.

188. The opposite pieces of each frame are mark... with a saw cut, termed a score, at their middle, on the upper side. The scores serve to fix the position which the frame should occupy when laid.

189. The scantling for top-frames is usually ... inches square; that of side and auxiliary frame... six inches for shaft over 4½ feet in the clear. For smaller shafts the scantling may be of smaller

dimensions.

190. The term Interval, both in shafts and galleries, expresses the distance between two adjacent frames added to the thickness of the scantling of the frame, measured in the direction of the axis of the shaft &c. With scantling and sheeting of the usual dimensions, the interval should not be greater than 3½ ft.

191. **Prob. Fig. 3.** The depth of a shaft, and the height of a gallery to lead from the bottom of the shaft, being given, to estimate the shaft interval.

Add together the height of the gallery frame from the top of its ground sill, the thickness of the top sheeting, and the thickness of the shaft frame; to this sum add 2 inches for free space, between the gallery frame and the shaft frame next above it, to introduce the top sheeting. Subtract this sum from the depth of the shaft, and divide the remainder into any convenient number of equal, or unequal intervals, each not greater than 3½ feet.

Example. Let the depth of the shaft be 22 ft, and the height of the gallery 4'. 6". Then:

From ground sill to exterior of top sill	4'. 11".
Top sheeting	0. 1.
Shaft frame	0. 4½.
Free space	0. 2.
Total	5. 6½

This taken from 22 ft leaves 16'., 5½", which can b
divided into four intervals of 3'. 4" each, leaving o
interval of ●'. 1½", which may be placed either at
or bottom, but best in the latter position.

192. To construct the foregoing shaft in a
soil, there will be required a top frame; 5 side
frames for the intervals above estimated; 2 for
the remaining lower portion of the shaft, one a
iary frame; 4 battens for each interval of the
of the interval added to the thickness of the sh
frame; from 12 to 20 square pickets about 18" lon
with the machinery and mining tools requisite
the operation.

193. The work is commenced by driving a
to mark the axis of the shaft, and two others wh
with the first are in the vertical plane containi
the axis of the gallery. A level bed is then ma
for the top frame, the pieces of which are accur
laid, and confined by pickets, one at the end
each piece, care being had to drive the two pic
of each piece together, so that its true position
be kept. Other pickets may be driven tempora
on the outside of the frame at the angular po
After the frame is laid the accuracy of its posi
is tested by seeing whether the distances fro

the center of the central picket to the interior angular points, or in other words the semi-diagonals, are equal. If they are the position is correct.

194. The excavation is now commenced, and, if the crumbling of the soil does not interfere, may be carried as far as the position of the first side frame; the sheeting boards, inserted between the soil and the exterior of the top frame, being gradually advanced with the excavation; here the first side frame is hung by four battens, two being nailed to each piece of the opposite sides of the top frame, and to the two corresponding pieces of the side frame, the halvings of which are turned upwards; after these pieces are adjusted by their scores, and fixed, the other two pieces are laid on them, the halvings down, and secured by nails.

195. This frame being fixed, the ends of sheeting of the next interval may be inserted between it and the sheeting of the first interval, and the excavation continued. The soil now becoming troublesome by its crumbling, measures must be taken to retain it firmly until the second frame is laid. For this purpose the auxiliary frame Fig. 4. is introduced, and hung midway in the interval, like the usual frames. The sheeting which thus far has been gradually ad-

vanced with the excavation, is also inclined outw
at bottom, to gain room for the auxiliary frame,
wedges, inserted between the boards of the two int
After the auxiliary frame is fixed, the excavatio
and sheeting are carried on to the bottom of the v
val, the next frame hung, and the sheeting for
new interval introduced. The auxiliary frame
now removed and placed in the next position w
reached by the excavation. The work will proce
in this order until the shaft is completed; wh
so, a picket is driven in the bottom, Fig. 5. to m
the central point.

196. A sketch, made to a suitable scale, sho
be in hand for immediate reference in conducting
such works. This is more particularly necessary f
gallery work, the sketches for which should be ve
accurately drawn, referenced and numbered; as th
serve not only for reference to guide the miner, bu
to determine positions and dimensions of some of th
important portions.

197. Timber Galleries. A gallery which leads f
another is termed a Return; and is called Oblique,
Rectangular; according to whether the projections
the axes of the two galleries make a right or an
acute angle. The gallery from which the return is

is termed Gallery of Departure. When the floor of the return rises, or falls from that of the departure the return gallery is termed Ascending or Descending.

198. To make a working sketch of a combination of galleries the projections of the axes are first laid out; their points of intersection marked; and the distances, and references between all the points written. The half width of each gallery in the clear being next set off on each side of its axis, a line is drawn for it, then one parallel and exterior to it at the thickness of the gallery frame, and finally a second to mark the exterior line of the sheeting.

The line **C D** (**Figs. 6.7.8.**) is the axis of the gallery of departure. and **A B** that of the return. The line **a b** is the exterior line of the gallery frames; **c d** the exterior line of the same; **e f** that of the sheeting The corresponding lines for the remaining half of the gallery of departure, and those of the return will be readily recognised. The frames **m**, and **m'** bound the entrances to the returns; and those **u**, **v** of the auxiliary return, the entrance to the oblique return (**Fig 8.**).

The case of a change of direction in a gallery is shown in (**Fig. 9.**). Here to obtain room for the miner to handle the sheeting &c, an end of an auxiliary gallery is made off, on the salient angle of

the break, just large enough for the object in view. Having set off these lines, the points of intersection of the exterior lines of the sheeting of the return with the exterior and interior lines of the frame of the gallery of departure are marked, as follows, to determine the distance to be left between the two frames of the gallery of departure, between which the entrance to the return is placed: 1st When the projections of the axes make a right angle then the intersections of the exterior lines of the sheeting with the interior lines of the frames are marked, The entrance to the return will be equal to the distance between the exterior lines of the sheeting of the return 2nd When the angle is between 45° and 90°, the intersection o of the exterior line of the sheeting of the return, which lies within the angle formed by the axes, with the exterior line c d of the gallery frame and that o' of the other exterior line of the sheeting with the interior line of the same frames being marked, will give the points between which the frames of the gallery of departure must be placed to form the entrance. 3a When the angle between the axes is less than 45°. the frames bounding the entrance to the return would fall too far asunder. It will therefore be requisite to make a rectangular

auxiliary return from the gallery of departure, into which the oblique return will have its entrance. To determine the position of the rectangular return, Fig. 8. a line r s is first drawn exterior to the sheeting of the gallery of departure, and at a distance from it equal to the thickness of the frames to be used for the auxiliary return; the intersection o of the exterior line of the sheeting, which lies within the angle of the axes, and the last line drawn being marked, will give the point through which the inner line of the frames of the auxiliary return is to be drawn. This line being determined, all the other lines for this return can be readily set out. The rest of the problem will be treated as in the second case.

199. From an examination of the above cases, it will be seen that the object to be accomplished is so to place the two frames of the gallery of departure, which bound the entrance to the return, that the stanchions of these frames shall not be in the way of the miner, when pushing forward the side sheeting; or, in other words, if the return were a box that could be pushed forward, like a drawer, in the direction of its axis, the stanchions in question should not hinder this movement.

Several other problems of a like character

may present themselves in returns, and in changes
in galleries, which it will be unnecessary to treat
as the illustrations above given will readily sugge
methods to be adopted for their solution.

200. Having set off all the lines on the wor
sketch, and marked the positions of the differen
&c, at the junctions of the galleries, their forms, d
and also their exact positions with respect to any
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sketch, and be written upon it for reference in con
ing the work. For example in Fig. 7, the det
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last should not be placed farther than an ordinary interval from the farthest point of q.

202. Prob To estimate gallery intervals. Having determined, by means of the working sketch, the landing and their frames with respect to the points of intersection of the axis of the gallery of departure with those of the returns, the intervals of this gallery can be calculated, and their positions marked out on the sketch. The manner of making this estimate will be best illustrated by the following example.

Let **A B** = 118 feet, **Fig. 10**. be the total length of a gallery of departure, estimated horizontally along its axis, from the central picket of the shaft from which the gallery starts. At the point **C**, 44 ft. from **A**, the axis of a rectangular return commences; and at **D**, at 44 ft. farther, that of an oblique one. The part **A C** of the gallery **Fig. 11**. is to be a common great gallery; the part **C D Fig. 12** a common gallery; and the part **D B Fig. 13** a great branch. With these data, it is required to determine the intervals for the different portions of the gallery.

To find the interval for the first portion **A C**, substract from the total distance, 44 feet, the following aggregate,

Half the width of the shaft in the clear . . . . 2. 2".

The thickness of the lowest shaft frame . . . . . 0'. 4½.
Half the width of the landing at C . . . . 2. 0½.
The thickness of a gallery frame at the landing. 0. 5.
5'. 0.

which leaves 39 ft, to be divided into suitable intervals, which may be done by making twelve of them, each 3 feet 3 inches.

The intervals of the portion C D will be found as follows, from 44' take the following sum,

Half the width of the landing at C . . . . 2'. 0½.
Thickness of the landing frame . . . . . 0. 5.
The distance from D (as found from sketch) to the landing frame beyond . . . . . 0. 9.
Thickness of gallery frame at landing D . . . 0. 4½.
3'. 7½.

which leaves 40 ft. 5 in. This can be divided into nine intervals each 3'. 1", and four of 3'. 2" each.

To find the intervals for the part D B, from 30 ft. take the following aggregate,

Distance from D to frame of landing beyond it . 4'. 5".
Thickness of landing frame beyond D . . . 0. 3½.
Thickness of last frame at B . . . . . 0..
5'. 0

This leaves 25 ft. which can be divided into six intervals of 3'. 2" each, and two of 3 ft.

203 In setting the ground sills of frames in ascending, or descending galleries, a small cubical block of wood, termed a Slope-block is used. This is a cubical block, the edge of which is equal to the difference of level between the ground sills of an interval. To determine the height of the slope-block, for any portion of a gallery where the intervals are equal, or nearly so, the difference of level or of reference of the two extremities of the portion must be divided by the number of intervals. Thus, in the portion of the gallery from **A** to **C**, **Fig. 10**. there is an ascent of 5′, or 60″, and twelve intervals; the edge of the slope-block will therefore be $\frac{60''}{12} = 5''$. In the portion from **C** to **D**, there is a fall of 4′. 1″, or 49″, and thirteen nearly equal intervals; the edge of the slope-block will therefore be 3″,7 nearly.

204. In loose soils, besides the ordinary gallery frames, there is required, as for shafts in the same soils, an auxiliary gallery frame. This frame **Fig. 14**. **o**. **Fig. 15**. is somewhat wider than the ordinary gallery frame, and somewhat lower than it. Its cap-sill is rounded on top, and has two mortices on its lower side, to receive the tenons with which the two stanchions are finished. The mortices are a little longer than the tenons; the latter being confined in them by wedges when the frame is set up. To adjust the frame when

set up a pair of sliding wedges is placed under each end of its ground sill. By these various contrivances the frame can be readily set up or taken apart.

205. To explain now the practical operations in driving a gallery, let an example be taken where the soil is loose, and the floor of the gallery rises from the point of departure. In this case the first frame of the gallery o **Fig. 16** must be set up within the shaft, and against the shaft frames on the side from which the gallery is to open. The ground sill of this frame being laid, the stanchions are secured to the intermediate shaft frames of the last interval by battens; and the top sill fastened. A horizontal beam **c**, is then secured to the under side of the top shaft frame of the same interval, to preserve the proper slope for the top sheeting when inserted, wedges being placed between this beam and the sheeting board for this object. A like arrangement for the side sheeting may be made if necessary. The excavation of the gallery is now commenced at top, by forcing down with a crow-bar the sheeting of the shaft, on the side of the gallery. The earth is removed gradually forwards and downwards, and the gallery sheeting advanced at the same rate. When the excavation has reached as low as the intermediate shaft frame, the piece of it that sustains the lowest portion of the sheeting is remo

to allow the excavation to proceed. When, in the half ~~this way~~ the earth is removed as far as the middle of the first interval, the auxiliary gallery frame Fig. 15 is set up, to support the top and side sheeting until the second gallery frame is placed. To place this last frame, the position of the ground sill is first determined, Fig. 17 by placing the slope-block o on the ground sill first laid, and then, by a common mason's level, A upon the side of which the interval is marked, laid upon the slope-block, bringing the top of the ground sill on the same level as that of the slope-block. The sill being adjusted and firmly secured, the stanchions are next set up, and secured by battens to the stanchions of the first frame, and the cap-sill is secured in the last place. The adjustments of the stanchions and cap-sill are made by an ordinary plumb-line, by means of which the edges of the stanchions are placed vertically, and the scores on the cap and ground-sills brought into the vertical plane of the axis of the gallery.

The battens are placed horizontally. In a level gallery they are nailed alternately at 4 and 8 inches below the cap-sill. In others Fig. 17 they are nailed 4 inches below the lower of the cap-sills of the two frames which they unite; this will bring them at 4 inches added to the height of the slope block

below the other.

The auxiliary frame is not taken down until wedges have been placed between the sheeting and the frame last placed in order to introduce the boards for the next interval; and these last are kept in the proper direction, as the excavation is advanced, by wedges inserted between them and the sheeting of the interval finished.

206. **Branch Galleries à la Hollandaise.** These galleries are of the same dimensions as small branches: the frames are made of plank; they are placed touching each other, and serve at the same time both as frames and sheeting.

Each frame consists of four pieces; the stanchions have a tenon at each end, Fig. 18, fitting into notches cut in the cap-sill and ground-sill to receive them.

When the gallery is an ascending or descending one, the ends of the stanchions are cut obliquely, in order that their sides may always be vertical.

Fig. 19. is a plan and section of this description of gallery.

207. **Shafts à la Boule.** The shafts are lined with frames made of plank, connected together as shewn in Fig. 20.

In **Fig. 21.** a section of a shaft à la Baule is shewn, which is sufficiently explanatory to render any other description unnecessary.

This kind of shaft can only be used with advantage in favorable soil, on account of the difficulty of introducing the frames sufficiently near each other: they are commonly placed 1 foot apart, as shewn in the figure. Large gabions, 6 feet long, and from 3 feet 6 inches to 4 feet in diameter, are sometimes used for lining shafts near the surface, smaller gabions being introduced as the work is proceeded with.

208. Construction of permanent galleries.

When the floor of the gallery is not more than 10, or 12 feet below the surface, it will be generally best to open a trench for the work. The width of the trench at the bottom should be the same as the gallery from out to out. If the soil is very firm the sides of the excavation may be made nearly perpendicular; at 6 feet above the bottom of the trench a berm 3 feet wide should be left, and at 6 feet above this another, and so on for every additional depth of 6 feet. These berms serve the place of scaffoldings to pitch the earth out.

If the soil is very loose the slopes will require to be sustained by a sheeting to prevent the earth from caving in.

After the masonry is completed the excavated earth is carefully replaced.

209. When the construction is made entirely under ground, a wooden gallery is first formed, the width of which between the frames in the clear, Fig. 22. is equal to the width between the piers of the permanent gallery from out to out; it height being such that there will be 6 inches between the crown of the arch on the exterior and the cap-sills. The top and side sheeting should lap about 8 inches.

When the gallery is completed, a new set of ground sills are laid along side of those of the gallery, their length being equal to the width of the permanent gallery in the clear, Fig. 23, a new set of stanchions o,o are set up on these sills, to support a new set of cap-sills of the same length as those of the gallery. Vertical boards a are placed along side the stanchions of the wooden gallery, and are buttressed against the sheeting by two horizontal pieces of scantling, c, c, one near the top, the other near the bottom of the gallery. When this new arrangement is completed the frames of the gallery first set up can be taken down, and the masonry commenced.

The foundations of the piers Fig. 24 are laid with an interior offsett of 6 inches. The piers are then

carried up, the lower horizontal buttress being gradually shifted up, so as not to interfere with the work, and the lower courses of the side sheeting which have now become unnecessary being removed. When the piers are completed the stanchions are taken down and replaced by props p,p resting on the outside of the tops of the piers.

When this change has been made, the way is clear for turning the arch. For this four common centres A,A. Figs 25,26 made of boards, will be requisite. Each of these centres is 18 inches broad and is secured to a rectangular frame o, of small scantling of the same breadth, and as long as the span of the arch. Each centre thus prepared rests upon a trestle q,q, of sufficient height to bring the centre in its true position to receive the masonry.

The masons to expedite the work commence at the middle point of the gallery, where two of these centers are placed together, and close the arch over them; the other two centers are then placed along side of these, and the arch in like manner is closed over them; the two first are then taken down, and removed to the outside of the two last set up, and the arch is thus carried on towards the two ends. The wood work of the gallery is taken down as fast as the masonry supplies its place.

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in galleries, which it will be unnecessary to treat here,
as the illustrations above given will readily suggest the
methods to be adopted for their solution.

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Half the width of the landing at C . . . . . 2'. 0
Thickness of the landing frame 0. 3
The distance from D (as found from sketch) to
the landing frame beyond 0. 9
Thickness of gallery frame at landing D . . . 0. 4
3'. 4

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Thickness of last frame at B 0. 3
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set up a pair of folding wedges is placed under each end of its ground sill. By these various contrivances the fram can be readily set up or taken apart.

205. To explain now the practical operations in driving a gallery, let an example be taken where the soil is loose, and the floor of the gallery rises from the point of departure. In this case the first frame of the gallery o **Fig. 16** must be set up within the shaft, and against the shaft frames on the side from which the gallery is to open. The ground sill of this frame being laid, the stanchions are secured to the intermediate shaft frames of the last interval by battens, and the top sill fastened. A horizontal beam c, is then secured to the under side of the top shaft frame of the same interval to preserve the proper slope for the top sheeting when inserted; wedges being placed between this beam and the sheeting board for this object. A like arrangement for the side sheeting may be made if necessary. The excavation of the gallery is now commenced at top, by forcing down with a crow-bar the sheeting of the shaft, on the side of the gallery. The earth is removed gradually forwards and downwards, and the gallery sheeting advanced at the same rate. When the excavation has reached as low as the intermediate shaft frame, the piece of it that sustains the lowest portion of the sheeting is removed

to allow the excavation to proceed. When, in the usual way, the earth is removed as far as the middle of the first interval, the auxiliary gallery frame Fig. 15 is set up, to support the top and side sheeting until the second gallery frame is placed. To place this last frame, the position of the ground sill is first determined, Fig. 17 by placing the slope-block o on the ground sill first laid, and then, by a common mason's level, A upon the side of which the interval is marked, laid upon the slope-block, bringing the top of the ground sill on the same level as that of the slope-block. The sill being adjusted and firmly secured, the stanchions are next set up, and secured by battens to the stanchions of the first frame, and the cap-sill is secured in the last place. The adjustments of the stanchions and cap-sill are made by an ordinary plumb-line, by means of which the edges of the stanchions are placed vertically, and the scores on the cap and ground-sills brought into the vertical plane of the axis of the gallery.

The battens are placed horizontally. In a level gallery they are nailed alternately at 4 and 8 inches below the cap-sill. In others Fig. 17 they are nailed 4 inches below the lower of the cap-sills of the two frames which they unite; this will bring them at 4 inches added to the height of the slope block

below the other.

The auxiliary frame is not taken down until wedges have been placed between the sheeting and the frame last placed in order to introduce the boards for the next interval; and these last are kept in the proper direction, as the excavation is advanced, by wedges inserted between them and the sheeting of the interval finished.

206. Branch Galleries à la Hollandaise. These galleries are of the same dimensions as small branches: the frames are made of plank; they are placed touching each other, and serve at the same time both as frames and sheeting.

Each frame consists of four pieces; the stanchions have a tenon at each end, Fig. 18, fitting into notches cut in the cap-sill and ground-sill to receive them.

When the gallery is an ascending or descending one, the ends of the stanchions are cut obliquely, in order that their sides may always be vertical.

Fig. 19. is a plan and section of this description of gallery.

207. Shafts à la Boule. The shafts are lined with frames made of plank, connected together as shewn in Fig. 20.

In Fig. 21. a section of a shaft à la Baule is shewn, which is sufficiently explanatory to render any other description unnecessary.

This kind of shaft can only be used with advantage in favorable soil, on account of the difficulty of introducing the frames sufficiently near each other: they are commonly placed 1 foot apart, as shewn in the figure. Large gabions, 6 feet long, and from 3 feet 6 inches to 4 feet in diameter, are sometimes used for lining shafts near the surface, smaller gabions being introduced as the work is proceeded with.

208. **Construction of permanent galleries.** When the floor of the gallery is not more than 10, or 12 feet below the surface, it will be generally best to open a trench for the work. The width of the trench at the bottom should be the same as the gallery from out to out. If the soil is very firm the sides of the excavation may be made nearly perpendicular; at 6 feet above the bottom of the trench a berm 3 feet wide should be left, and at 6 feet above this another, and so on for every additional depth of 6 feet. These berms serve the place of scaffoldings to pitch the earth out.

If the soil is very loose the slopes will require to be sustained by a sheeting to prevent the earth from caving in.

After the masonry is completed the excavated earth is carefully replaced.

209. When the construction is made entirely under ground, a wooden gallery is first formed, the width of which between the frames in the clear, Fig. 22 is equal to the width between the piers of the permanent gallery from out to out; it height being such that there will be 6 inches between the crown of the arch on the exterior and the cap-sills. The top and side sheeting should lap about 8 inches.

When the gallery is completed, a new set of ground sills are laid along side of those of the gallery, their length being equal to the width of the permanent gallery in the clear, Fig. 23; a new set of stanchions o,o are set up on these sills, to support a new set of cap-sills of the same length as those of the gallery. Vertical boards a are placed along side the stanchions of the wooden gallery, and are buttressed against the sheeting by two horizontal pieces of scantling, c, c, one near the top, the other near the bottom of the gallery. When this new arrangement is completed the frames of the gallery first set up can be taken down, and the masonry commenced.

The foundations of the piers Fig. 24 are laid with an interior offsett of 6 inches. The piers are then

carried up, the lower horizontal buttress being gradually shifted up, so as not to interfere with the work, and the lower courses of the side sheeting which have now become unnecessary being removed. When the piers are completed the stanchions are taken down and replaced by props p, p resting on the outside of the tops of the piers.

When this change has been made, the way is clear for turning the arch. For this four common centres A, A. Figs. 25, 26 made of boards, will be requisite. Each of these centres is 18 inches broad and is secured to a rectangular frame o, of small scantling of the same breadth, and as long as the span of the arch. Each centre thus prepared rests upon a trestle q, q, of sufficient height to bring the centre in its true position to receive the masonry.

The masons to expedite the work commence at the middle point of the gallery, where two of these centers are placed together, and close the arch over them; the other two centers are then placed along side of these, and the arch in like manner is closed over them; the two first are then taken down, and removed to the outside of the two last set up, and the arch is thus carried on towards the two ends. The wood work of the gallery is taken down as fast as the masonry supplies its place.

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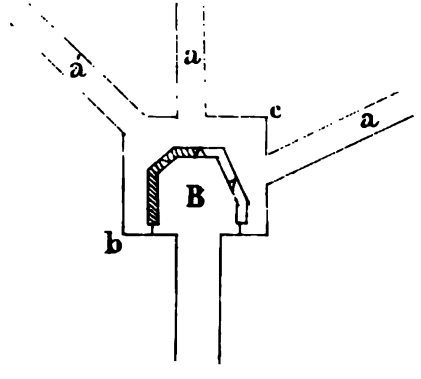

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212. The sides of the galleries are also arranged either with grooves, or offsets, so that barriers may be made within them for defence against the enemy's miner when he penetrates into the gallery. In some cases a simple pit is dug across the gallery and covered by boards which are taken up when the communication is required to be cut off.

213. **Mine Chambers** The chamber of a mine is a cavity **A** formed to receive the charge of powder. Fig 27.

When the chamber is made at the end of a gallery, the centre of the chamber is placed on a level with the floor of the gallery. It is usually better to place the chamber at the end of a small branch return on one side. When the charge is not to be exploded immediately, or the ground is much saturated with moisture, it should be placed in a well-pitched wooden case, or in a good cask, or in a wooden case covered with tarpaulin, or any like expedient adopted that may be at hand - the best receptacle is a water-tight tin case.

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The bag should be of close texture and well sewed.

These troughs are made 1½ inch square in the clear. The four pieces of which they are composed, or the sill, sides and top, or cover are from ¼ to ½ inch each in thickness.

A trough should penetrate the powder-case about 4 inches, and should exactly fit the opening left for it.

It is fastened to the floor of the branch by nails through the sill which enter smal pickets driven to receive them. Sometimes the sides of the trough are confined by pickets to prevent its being disturbed.

The different lengths of the trough should be cut to fit exactly. Each portion of the trough should have its cover well fitted, and secured with one peg only, in order that it may readily be removed to introduce the powder-hose.

must be made when proportioning the trains, each elbow being valued at 3 inches; thus if on one side of the point where the principal trough connects is one elbow more than on the other, the principal trough should be placed 3 inches nearer to the charge on that side, which is done by placing it 1½ inches from the central point towards that side. Square elbows impede somewhat more than oblique ones.

Experience has shown that two powder-hoses may be placed within 18 inches of one another, if covered with earth and exploded separately without interference.

216. **Tamping.** Mines are tamped either with earth and sods with earth and wood, or with sand bags.

To tamp a branch with sods and earth, the miner first fills the branch with sods for a length of 3 feet, commencing at the chamber. The sods are piled in regular layers, the precaution being taken to throw loose earth over each layer, to fill the voids between the sods. When this length is finished the miner fills in for an additional 3 feet with earth which should be well packed. Another length of sods is laid of 3 feet, and so alternately through the entire branch.

To tamp with wood and earth, a stout shield of thick boards is first placed across the branch and firmly buttressed against the chamber, the branch

is then filled with well packed earth resting against the shield for a length of 3 feet; billets of round, or square timber are then packed across the branch for a length likewise of 3 feet, another length of earth of the same thickness is packed in against the wood; and so on for the entire length to be tamped, finally at the end of the tamping another shield is set up and firmly buttressed.

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The length of tamping is regulated by the line of least resistance of the mine the part of the branch tamped equal to twice this line. This length must be measured in a right line from the chamber to the point of the branch wher the tamping terminates and not along the windings, or elbows of the branch.

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Stretch the extremity of the hose upon a sheet of paper, and sprinkle some dry fine powder on it; cover this powder over with another sheet of paper, secured at its four corners with dry earth or stones; pass the monk through a hole in the upper sheet, and let it project half its length above it, its base being plunged in the powder, on the bottom sheet; set fire to the monk at top with another piece of agarick, termed an *injormer* of the same dimensions and form as the first, and retire quickly.

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At 6 inches from the top of the box a horizontal slit is made in one of its sides, and grooves in the two adjacent to it to receive a piece of board, which ought to slide freely in this arrangement. In the lower part of the box, an opening is left on the side opposite the one cut for the slide, to admit the powder-hose.

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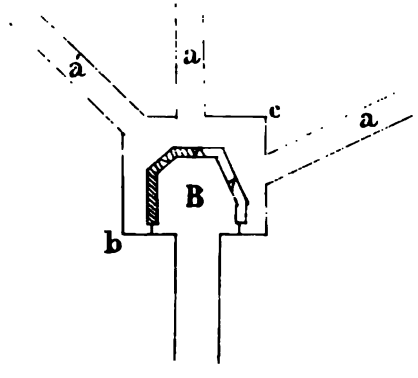

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The trough is said to make an elbow when it changes its direction. The pieces forming an elbow should be firmly yet simply connected. Figs. 28 and 29. shew the most common forms of elbows.

215. **Proportioning Trains.** When several mines are to be fired at the same moment, it is necessary so to proportion their trains, that, starting from the same point, the distances in time from that point to the charges may be all equal. The following cases show the manner of obtaining this result.

For two charges, Fig. 30 place a trough on the shortest line from the one to the other, mark the centre of it, and let the principal trough join it in that point

For three charges Fig. 31 connect, as above, the two which are nearest. Let a trough from the middle point of this to the third charge, bisect the whole length of trough between this third charge and either of the others, then let the principal trough be joind to this last point.

For four charges, Fig. 32, first connect them two and two, then join the central points, and proceed as above.

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must be made when proportioning the trains, each elbow being valued at 3 inches; thus if on one side of the point where the principal trough connects is one elbow more than on the other, the principal trough should be placed 3 inches nearer to the charge on that side, which is done by placing it 1½ inches from the central point towards that side. Square elbows impede somewhat more than oblique ones.

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To fire the train place the box against the extremity of the tamping, and secure it well; tie

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The ordinary rocket for this service co
3/4 of an ounce of a composition formed 2/5 of fi
powder, 2/5 saltpetre, and 1/5 of charcoal-dust.
ingredients should be very carefully mixed, to m
the rocket burn uniformly. Its usual diameter
nearly 3/4 of an inch, and entire weight about
ounce. Rockets may be made much smaller whe
required.

218. **Blasts.** Blasts are small chambers, or
made in rock, or masonry charged with powder.
forming of blast-holes requires the use of partic
tools, called borers, jumpers, scrapers, needles, and
tamping bars.

To form the blast-hole, two or three me
are required; one holds the borer with both han
while the head of of it is struck with sledge ha
mers by one or two others. The first turns the b

at each stroke so that the hole may be circular, and from time to time clears it out with the scraper.

When the hole required does exceed 15 inches in depth, it may be excavated in the above manner; but if 20 inches, or more, deep, the jumper is generally made use of. The miner holds the jumper in both hands, raises it, and lets it fall in the hole, turning it continually: he also clears the hole with the scraper. When the stone is of a very hard description, it is usual to pour water occasionally into the jumper-hole.

To load the hole, fill about one-fourth or one-third of it with powder, according to the nature of the stone. The charge for a depth of 18 inches is from 8 to 12 ounces.

To tamp and prime the blast-hole, the needle is first introduced plunging it well into the powder, and placing it on the smoothest side of the hole; then a layer of clay is laid on the powder, and is closely pressed down with the tamping bar.

Other similar layers are then laid, or layers of brick reduced to small bits, the needle being turned repeatedly. It is usual to press down the first layers with a bar of wood, the helve of a tool for instance, and the latter ones with the iron tamping bar. When the hole is thus filled up, a small shell of clay is formed

round the needle, which is then withdrawn, the
left by it is filled with fine powder, and it is fire
a monk or a piece of port-fire.

The use of the needle is often dispense
in which case the priming is rolled up in a she
brown paper, or it is introduced in straw stalks
into one another. This priming is placed in the
at the same time as the charge, so that it may
well into the latter. The tamping is then execut
before.

The use of the tamping bar and the ou
tamping may also be dispensed with, the hole bein
over the charge with very fine dry sand, poured in
out any pressure.

The many accidents that have happe
in priming blasts have let to the invention of p
fuses, which are made to burn somewhat in the sam
as the fuse in the small Chinese fire-cracker. Th
use is far safer than any of the former methods

For blasts under water the charge is in
in a water tight tin case and fired either by a g
current or a priming fuse which is protected fro
water by a small tube connected with the charg
leading to the surface of the water.

The result of many experiments has shew

in blasting rock a large portion of the powder (nearly half) may be saved by mixing with the remaining part fine dry saw-dust of elm or beech. In blasts exploded in this way, the effect is not the same as when the full charge of powder is used; the rock splits into fewer and larger pieces and to finish dividing them, a more frequent use of the sledge hammer is required.

219. **Demolitions.** The charges of mines intended to overturn masonry, are calculated as in a common soil, by using the proper quantities given in the preceding table for the different kinds of masonry to be destroyed.

220. **To Breach a Wall.** First ascertaine if practicable the thickness of the wall, and then proceed thus: —

First case. — When the wall is from 2 to 3 feet thick, place one or two barrels of powder against the lower part of it, and fire them.

Second case. — When the wall is from 5 to 6½ feet-thick place one or two charges under its foundations plumb with the centre of the wall.

Third case. — When the wall is from 9 to 12 feet-thick, open at the foot of it, or about 12" above the water-level, a branch gallery, which must be

at three fourths of the thickness of the wall, and so regulated that their craters may slightly run into each other Fig. 37.

When galleries cannot be driven at the proper level for the charge, as in the demolition of wharfs &c. shafts are sunk behind the revetment, or at a short distance in the rear of it, Fig 38, and branches are then driven to the positions for the charges; or, which is still better because it is more speedy operation, a shaft may be sunk for each charge

The depth of the shafts must be sufficient to admit of a proper length of tamping.

If at the same time with the wall a mass of earth in rear of it is to be destroyed, prolong the branches in the interior of the earth sufficiently to allow of the mines at the back of the wall exploding before those placed in the earth beyond Fig 39.

When there is a gallery Fig. 40, at the back of the revetment, the charges should be placed along this gallery, excavating chambers for them in the revetment at distances apart equal to twice their line of least resistance, viz. at two lined intervals.

The portions of the gallery in the rear of the charges are then tamped; at each end the length of the tamping should be equal to twice the line of least

resistance of the extreme charges.

The following method has been employed with success. Regarding as the line of least resistance the distance from the gallery to the exterior surface of the wall, imagine a row of common mines placed at two linear intervals throughout the length and calculate the sum of these charges, to which add one-half for a great gallery, place the whole charge in several heaps, with strong trains leading from one to another. Then tamp strongly and carefully the ends of the gallery, leaving the space intended to be demolished void. When the gallery is more than 2 yards wide and high, or if it have many issues difficult to tamp the charge of powder must be farther augmented to produce the desired effect.

223. **Demolition of Towers.** If the interior diameter of the tower be 6 yards or more, Fig 41 drive branches into the wall from the interior of the tower, and place charges so as to be a little nearer to the interior than to the exterior of the wall. When the tower is connected with walls, charges must be placed at their points of junction.

When the tower is but 4 or 5 yards in diameter Fig 42. sink a shaft to about the level of the bottom of foundations, and place a charge there corresponding to the line of least resistance measured from the centre

of the charge to the foot of the wall outside.

Cover the floor of the tower with two rows of small beams, then lay upon them two beams crossing, and halved into one another; and place upon these uprights abutting firmly against the masonry of the arch.

When a shaft cannot be sunk on account of water, and when the tower has loop-holes which prevent charges being placed in the walls, lay the charge on the floor of the tower enclosed in a strongly constructed case, propped on all sides against the masonry.

When the tower is square, and has several floors or stages, the charges may be placed at the four corners of the ground story, tamping the first floor.

224. **Demolition of Powder Magazins.**

Place charges in the piers and gable ends, so that their craters may slightly cross each other.

When time presses, a charge is laid on the floor of the magazine, the doors are barricaded, and it is fired with a hose led outside.

To determine the quantity of powder required for the heap, calculate the number of common mines required to overturn a revetment of the same length and thickness as the walls of the magazine, including the piers; add one half to the sum of the charges thus found

and place the whole in one heap in the centre of the magazine.

The above method is only applicable to magazines of not more than 150 square yards surface. If of greater capacity, the quantity first found should be increased 1/10 for every 15 square yards of additional surface, and be placed in two or more heaps connected with powder hose, to fire them simultaneously.

225. **Demolition of Bridges.** To destroy a bridge the piers of which are from 4 to 5 feet thick, place in one of the piers two charges of 130 to 160 lbs. each Fig. 43, and secure a plank to the bridge on which to place the powder-hose.

If the pier be from 6 to 10 feet thick, drive in the middle of it, parallel to its face, two small branches, at the ends of which place charges of from 200 to 230 lbs. each Fig. 44.

When there is not time to place charges in the interior of the piers, cut a trench over the key of the arch 18 inches deep, in which place 400 to 530 lbs. of powder.

This quantity of powder has broken semi-circular arches of 26 feet span, and 4½ feet thickness at the crown.

Another good method is to cut a trench in form of a cross, Fig. 44, over the middle of the arch, each

branch being about 10 feet long, and carried down to the extrados. Place in each branch 200 lbs of powder for an arch 3¼ feet thick, and cover the charges with timber, earth &c.

An arch may also be blown up by suspending an open trough under it with cords, and placing in it charges of powder similar to those already stated for trenches cut on the surface.

When the saving of powder is of consequence, sink a shaft down to one of the haunches Fig. 45, and place the powder in one mass, unless the bridge be very wide: an arch of 18 inches, or 2 feet thickness of a bridge 20 feet wide, may thus be destroyed with 45 lbs. of powder, if a loading can be applied over the charge, giving an equal resistance to the arch.

If the bridge is more than 20 feet wide, two shafts must be sunk, and charged as before described. When the side walls of the bridge above the piers are slightly built, and the loading of the arch is of loose rubbish, a small gallery should be driven about 5 or 6 feet from the arch stones, along the axis of the bridge, as at A, Fig. 45; a return is then made towards the arch, and the charge is placed in contact with the extrados. Bridges of timber may be blown up by suspending barrels of powder under one or several bays.

226. Demolition of Houses. Begin by undermining

A rocket 6 inches long, will travel 100
at least, and its velocity is so great, that two roc
fired at the same moment, to run very different
tances, leave no perceptible interval in the time
their arrival. This property of rockets renders
to proportion the trains of mines to be fired sim
taneously, which with powder-hose requires g
nicety.

The ordinary rocket for this service co
3/4 of an ounce of a composition formed 2/5 of f
powder, 2/5 saltpetre, and 1/5 of charcoal-dust.
ingredients should be very carefully mixed, to
the rocket burn uniformly. Its usual diameter
nearly 3/4 of an inch, and entire weight about
ounce. Rockets may be made much smaller wh
required.

218. **Blasts**. Blasts are small chambers, or
made in rock, or masonry charged with powder
forming of blast-holes requires the use of partic
tools, called borers, jumpers, scrapers, needles, and
tamping bars.

To form the blast-hole, two or three m
are required; one holds the borer with both han
while the head of of it is struck with sledge h
mers by one or two others. The first turns the

at each stroke so that the hole may be circular, and from time to time clears it out with the scraper.

When the hole required does exceed 15 inches in depth, it may be excavated in the above manner; but if 20 inches, or more, deep, the jumper is generally made use of. The miner holds the jumper in both hands, raises it, and lets it fall in the hole, turning it continually: he also clears the hole with the scraper. When the stone is of a very hard description, it is usual to pour water occasionally into the jumper-hole.

To load the hole, fill about one-fourth or one-third of it with powder, according to the nature of the stone. The charge for a depth of 18 inches is from 8 to 12 ounces.

To tamp and prime the blast-hole, the needle is first introduced plunging it well into the powder, and placing it on the smoothest side of the hole; then a layer of clay is laid on the powder, and is closely pressed down with the tamping bar.

Other similar layers are then laid, or layers of brick reduced to small bits, the needle being turned repeatedly. It is usual to press down the first layers with a bar of wood, the helve of a tool for instance, and the latter ones with the iron tamping bar. When the hole is thus filled up, a small shell of clay is formed

round the needle, which is then withdrawn, the
left by it is filled with fine powder, and it is fired
a monk or a piece of port-fire.

The use of the needle is often dispensed
in which case the priming is rolled up in a sheet
brown paper, or it is introduced in straw stalks t
into one another. This priming is placed in the h
at the same time as the charge, so that it may p
well into the latter. The tamping is then executed
before.

The use of the tamping bar and the ordi
tamping may also be dispensed with, the hole being
over the charge with very fine dry sand, poured in
out any pressure.

The many accidents that have happen
in priming blasts have let to the invention of pr
fuses, which are made to burn somewhat in the sam
as the fuse in the small Chinese fire-cracker. The
use is far safer than any of the former methods.

For blasts under water the charge is ins
in a water tight tin case and fired either by a ga
current or a priming fuse which is protected from
water by a small tube connected with the charge
leading to the surface of the water.

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Third case. — When the wall is from 9 to 12 feet-thick, open at the foot of it, or about 12" above the water-level, a branch gallery, which must be

driven to the centre of the wall; then make two p
pendicular returns to this branch, and place th
powder at their extremities, Fig. 35.

221. **To Breach a Wall with a Terrace** Open at the foot of the wall, or 12" above the leve the water, a branch perpendicular to the direct of the revetment; drive it through the wall th earth, then make to the right and left two o branches, following the back of the wall, and eac length equal to its thickness, place the charges end of these branches, so that the centre of each may be flush with the back of the wall.

222. **Demolition of Revetments.** When th revetment is without counterforts, or the counterfo are not more than 3 feet thick several branches a driven perpendicular to the direction of the revet at equal distances apart. The charges used shou produce craters that will cross each other a lit

When the wall has counterforts of th usual dimensions, the charges are placed as f as practicable, in the lines of their axes and their junction with the revetment. Fig. 36.

When time presses instead of ma one branch for each pair of charges, one is mad each charge; and the whole of the charges are p

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226. **Demolition of Houses.** Begin by undermining

the windows and doors, and cutting away the piers
them, so as to leave the building supported by a
only, nearly square. Place in each of the piers a
of from 13 to 16 lbs. of powder, tamping well with
Proportion the trains to the different charges, so that
may be simultaneously exploded. If pressed for
resort to the same methods as for towers and galler

To destroy palisades, or gates, doors &c the
method is to suspend a leathern bag filled with
either with a forked stick, a strong gimlet, or a sto
copper nail, against the gate, or palisade. The bag
have about an inch of port-fire firmly secured in
side of it, to communicate the fire to the charge.
throw down a strong palisade, from 30 to 50 lbs. of
should be used. To burst open a town-gate, 60 to
lbs. of powder will be required.

227. Forgasses. — Mines are so called when
at the bottom of small shafts from 9 to 12 feet deep
powder is lodged in one of the sides of the shaft,
it is fired from a secure spot by means of a
hose brought up one side of the shaft, and carried
a trough parallel to the ground 5 or 6 feet below the
face. When there is no occasion to fear that shells may fall o
part where the trough is laid, ; it will
sufficient to place it 2 or 2½ feet under the gro

The powder-case and trough should be well pitched, the shaft tamped in the strongest manner, and the earth round about the shaft be dug over, that nothing may be indicate to the enemy the position of the fougasse.

228. **Shell Fougasses.** Shells may be buried singly, or in small heaps, and be made to burst either under the ground, or on its surface.

If they are to burst under the earth, they must be sufficiently charged to produce a crater, through which the pieces are projected.

If they are to burst on the surface, the requisite quantity of powder to produce a crater and throw out the shells must be lodged under them, while these latter need only have a sufficient charge to burst them.

In all cases a box is used, Fig. 46. divided into two parts by a partition. The shells are placed in the upper part, their fuzes project through the partition, and extend from ½" to 1 inch below it.

In the lower part the hose only is placed when the shells are intended to produce their own crater, but powder sufficient to produce the crater is introduced when they are intended to burst on the surface of the ground.

Description of shell.	Full charge of the shell.	Depth at which the full charge produces a crater.
	lbs oz	
Calibre, 5½	1 0	2′ 0″
" 8	2 9	2 10
" 10	5 0	3 · 6
" 13	11 0	4 7

The effects produces by common and shell fougasses are very limited and only destructive near to their craters, consequently they should not be exploded until the enemy is above them.

Counterscarp-Galleries.

229. When the ditches cannot be swept by the fire of the parapet, a counterscarp-gallery offers one of the best means of flanking them with musketry.

The most simple arrangement of this defence consists (Pl. IX. Fig. 1.) of an arched gallery A, or passage way, behind the counterscarp wall, with a range of loop-holes pierced in the counterscarp wall.

The width of the gallery should be at least 6 feet, and its height to the crown of the arch 7 feet. The capping of the arch should be at least 3 feet below the top of the counterscarp-wall to preserve the arch from the effects of shells. The loop-holes should be 3 feet apart measured between their centre points, their height above the floor of the gallery 4½ feet, and above the bottom of the ditch at least 6 feet. Vent-holes are placed above the loop-holes for the escape of the smoke.

As the form of arch usually adopted for these galleries is the full centre, it has been found that, with the dimensions above given, (and which, with the ordinary height of counterscarps, admit of but slight augmentation,) the men placed at the loop-holes are in rather a constrained position for a prompt use of their pieces, besides being liable to be jostled when there is any movement of troops in the gallery. To

remove these inconveniences, a different arrangement has, within some years back, been adopted by the French engineers. This plan consists of a range of arched recesses, A. (Pl. IX. Figs. 2. 3 4.) immediately in rear of the contrescarp wall, of sufficient width and depth for the service of three loop-holes in each. The recesses open into a narrow arched gallery B in their rear which serves simply for a passage way that can be used without disturbing the men in the recesses.

The recesses are formed by building back from the counterscarp-wall short counterforts a, a. to the depth of the recesses. These serve as the piers of a range of oval arches which form the ceilings of the recesses. The arch of the gallery of communication springs from an abutment built parallel to the ends of the counterforts, and from the counterforts. Its rise is the same as that of the arch of the recess. These arches by their intersections thus form a system of right cylindrical half groined arches; the groins rise from the inner edges of the counterforts to the points of intersection of the top elements of the arches.

The arches are covered to the usual depth with earth. The floor of the passage way is on the same level as that of the recesses, and so placed as to leave sufficient height to the crowns of the

arches for the service of the gallery. The loop-holes are at the usual heights above the floor of the gallery and the bottom of the ditch. The one in the centre of the recess is arranged for direct fire; the other two are oblique, and have the same exterior opening as the two adjacent to them in the adjacent recesses. A vent-hole is placed in each recess immediately beneath the crown of the arch.

Scarp-Galleries.

230. When the command of the parapet is too great to bring its fire to bear on the ditches, or any other points to be guarded, resort may be had to a gallery in rear of the scarp wall, when the wall is not exposed to the enemys artillery within breaching distance.

The following is the usual disposition of this gallery. A range of relieving arches, **A**. (Figs. 5. 6. 7.) resting on counterforts, is built back from the scarp wall. Sufficient space is left beneath the arches, and between the counterforts, **B**, for the service of the loop-holes, which are pierced in the scarp wall, and so placed as to bring the points to be guarded within the range of their fire. The earth of the parapet and rampart **C** which covers the arches on top and in the rear, falling in its natural slope under the arches from the crown towards

the back of the scarp wall,) is levelled off at a suitable distance beneath the crowns of the arches, to form the floor of a gallery. The width of the floor is sufficient for the service of the loope-holes, and for a passage way behind which is made by door-ways **D** cut through the range of counterforts. When from the position of the floor, a sufficient width would not be left for it, were the slope of earth under the arch brought down to its level, it will then be necessary to build a thin wall a parallel to the back of the counterscarp wall, and at the distance from it for the width required. This wall rises from the level of the floor to the surface of the slope, and rests on an arch **b**, which springs from the two adjacent counterforts.

The loop-holes are at the usual height above the floor of the gallery. Vent-holes are placed under the crown of each arch.

Casemates.

231 Defensive casemates consist of a range of bomb proof arches to cover batteries, placed immediately in rear of a scarp, or a counterscarp-wall, both from shells and from the enemy's direct fire.

The bomb-proofs **Figs. 8. 9 10.** are formed by building back from the mask wall, **A** which covers

guns in front, counterforts B, which serve as the piers of the arches C. The width between each pair of counterforts, and their height above the floor of the casemate on which the plat forms of the guns are laid, are so regulated that there will be ample room for the service of the guns, of which seldom more than two are placed in each casemate. The counterforts and arch extend far enough back to cover all within the casemate from shells, when the casemate is not closed in the rear by a wall. The piers of the casemate are usually of stone and the arches of brick.

232. In the arrangement of defensive casemates several difficulties present themselves which require particular attention.

1st The mask wall and arch of the casemate must not be exposed to any position where the enemy might place a breach battery.

2nd The form of the embrasure pierced in the mask wall must be such as to embrace a wide field of view, and not at the same time present an opening of such width in the wall as to afford a fair mark to the enemy.

3d The smoke from the muzzle of the gun should be thrown well out beyond the face of the mask wall, and the smoke that escapes within the

casemate must be carried off rapidly through flues o
posed for this purpose.

The first of these difficulties has been fo
very formidable on land fronts, as positions can sel
be obtained for casemates upon which an enemy ca
bring his fire to bear, and speedily ruin any portio
the mask wall, or casemate arch exposed. On wa
fronts, for sea-coast defence, where the guns of shi
can alone be brought to bear against the masonry
its exposure is less objectionable; as, being a less vul
able material than timber, the preponderance of s
lies greatly on the side of the land defence.

233 Several expedients have been proposed t
tain, on land fronts, a fire, on points which are
particular value to the defence, from casemates s
placed that their masonry and guns can be mas
from the enemy's fire. For the defence of the bre
in the bastion face for example, it has been pr
to attain this object either by a casemate in the
of the bastion, so placed that its mask wall ca
covered by an orillon; or else by constructing the
with casemated flanks, which are covered from the
fire by an earthen mask, with arched openings, i
the line of direction of the guns, which are so dis
that whilst they permit the fire of the flanks to

its point they intercept that of the enemy upon the casemate in their rear.

234. A disposition of casemated defences exposed to the enemy's artillery has been made in some of the recent works constructed in France, (Figs. 11, 12, 13) in which the masonry of the casemate is masked by the parapet of the work. To effect this object, the mask-wall of the casemate A is thrown far enough to the rear of the scarp-wall to receive cover from the earth of the parapet B, in front of it, in which embrasures C, of the ordinary form and dimensions are made in the direction of the embrasures e' in the mask wall. The casemate arch is covered from shells by the earth of the parapet and rampart, and to present as little of its masonry as practicable to the fire in front the arch D is flattened, or lowered where it joins the mask-wall, and that portion of the wall which would be exposed through the earthen embrasure is covered by heavy timbers laid across the embrasure to break the effect of the shot that may attain this point.

235. In casemates for sea-coast defences (Figs. 8, 9, 10) as the mask wall is not as liable to be damaged as in land fronts, the 2nd and 3d points mainly demand attention. For the attainment of the former, the sole of the embrasure gradually narrows from the

exterior and interior to a line drawn across it nearly midway between its exterior and interior lines; and each cheek consists of two vertical planes a. c., which, by their intersection, form a salient angle towards the embrasure. The top or ceiling b of the embrasure is either arched or a plane surface. By this combination of par the embrasure is narrower on the exterior than on the interior face of the mask-wall; and the two cheeks gradually narrow inwards from these points. To accommodate the lateral motion of the gun to these positions of the cheeks, its carriage is placed upon a platform that traverses, or moves around a vertical axis at the centre of the sole d of the embrasure. This motion is given by a vertical cylindrical hole, drilled down through the masonry at this point, termed a pintle-hole, into which a strong iron bolt, or pintle fits and confines the tongue, or end of the platform, which is received into a recess, e, termed the tongue hole, cut into the masonry beneath the sole of the embrasure, and which is of a suitable form to allow the tongue to traverse between the extreme positions embraced in the field of fire of the gun.

To allow the smoke to clear the embrasure, and for the speedy escape of any in the casemate, a recess D is made in the wall, around the interior opening

of the embrasure, by which the muzzle of the gun is thrown farther outwards. From the top of this recess, a flue f, made in the mask wall, rises to the coping, through which the smoke in the casemate is carried off.

236. Besides the usual inconveniences of casemates, it has been found that when they occupy the two sides of a re-entering angle the smoke forms a stationary curtain before the embrasures, and prevents the object aimed at from being seen; and also that the concussion from the discharge on one side is so powerful in the casemates of the other as to prevent the simultaneous service of the guns on the two sides.

Casemates for mortars, consisting of a simple bomb-proof arch without mask, or rear wall, have been tried, but both the arch and piers have been found to show signs of injury from the concussion after a few discharges.

237. In small works, where flanking dispositions cannot be obtained from the enceinte, casemates for ditch defences, by guns of light calibre, or small carronades, have been arranged in rear of the counter-scarp wall. For a like object, small casemated towers, or caponnieres have been placed in the ditches. Each of these arrangements may not only secure works not flanked from surprise by escalade, but, by procuring

reverse views upon points where a breach can be ma
will retard their assault until the enemy gains posse
ion of the casemates, or forces the assailed from them.

Accessory Outworks and Detached Works.

238. Under the head of accessory outworks may
placed Counterguards, Horn-works, Crown-works, a
any other combinations of elementary parts which,
like the ordinary outworks, are in immediate relations
defence with the enceinte.

The object of these additional defences is u
to strengthen points of the enceinte which are weake
owing to some defect, or necessary consequence of its
general plan, by placing a greater number of obstac
to the approaches of the enemy on these points, or t
sweep by their fire ground which cannot be brough
under that of the main work.

239. Counterguard. A counterguard A. Fig. 14
holds the same relation to the faces of the bastion, in
advance of which it is placed, as the demi lune does
to its redoubt. In arranging a counterguard its face
should be so directed upon the flanks of the opposite
bastions that its scarp and ditch will be swept by a
portion of the flanks, and they should extend as
far as the shoulder angle of the bastion faces in the

rear to cover the latter from the enemy's breach batteries placed on any points beyond the counterguard.

240. **Horn-work.** This Fig 15. consists of a small bastion front placed in advance of a demi-lune, or a bastion, and is connected with the adjacent parts of the main defences by two lines of scarp-wall, parapet, & A,A termed the wings which unite with the salients of the front and are so directed on the adjacent parts of the main defences as to be flanked by them. When the horn-work is placed in advance of a demi-lune the ditches B, of its wings unite with those of the two adjacent bastions at points where they can be flanked by the fire of the bastion faces. When placed in advance of a bastion the wings receive directions so as to be flanke by the adjacent demi-lunes. The horn-work may in addition receive the ordinary outworks of a bastioned front.

It is objected to the horn-work that arranged as an outwork it adds but little to the defence, as it presents a very contracted front in an advanced position, which will be but a slight impediment to the enemy's approaches: that it exposes the faces of the bastion, or demi-lune, upon which its wings rest to the enemy's breach batteries, so soon as he establishes himself upon the portion of its glacis in the prolongation of the

ditches of the wings; and that in possession of the enemy the parapet of its wings effectually covers all his approaches within it, upon the main works in its rear, from the fire of the collateral portions of the main works.

241. **Crown-Works.** These consist of two or more bastioned fronts the extreme points of which rest either on the faces of two demi-lunes, or two bastions, from which these points are swept. As an outwork this combination is open to the same objections as the horn work; is more expensive; and presents greater difficulties in its arrangement.

242. **Detached-works.** A detached-work may form a part of the general system of defence of the main works, either by occupying points beyond the effective range of the fire of the latter, but which it is of consequence to prevent the enemy from seizing at the commencement of his operations; or by occupying points within the effective range of this fire on the line of the enemy's approaches. In the former case, the detached work, like any other isolated permanent-work, must be so arranged as to suffice for its own defence. In the latter it may be flanked, and its interior be swept, by the fire of some part of the main-works.

243. Of the various forms of the latter class of detached works the Lunette is the most simple, and lends itself best to the conditions that this class should satisfy. This work, to be of any value as a detached work, should be of sufficient capacity to hold a garrison capable of making a respectable defence, and be of sufficient strength of profile to secure it from a coup-de-main. To fulfil these requisites its salient angle should not be less than 60°. Its faces should be about 60 yards in length, and its flanks 20 yds, the latter being so placed as to sweep in the best manner the lateral ground. Its scarp, counterscarp and gorge must be revetted; the height of the first being from 21 to 24 feet; and that of the two last about 15 feet. The gorge wall may receive the form of a small bastioned front, to obtain a flanking arrangement for a better defence in case of the work being turned. Its ditch may be from 10 to 12 yds wide when dry; and from 20 to 25 yds when wet. The counterscarp throughout should be parallel to the direction of the faces, and the bottom of the ditch should gradually rise towards the gorge, (but not more than 6 feet in all so as not to decrease too much the height of scarp at this part) to allow the ditch to be thoroughly swept by the fire of the works in the rear which flank the lunette. The salient of the lunette should

not be farther than 300 yds from the parts of the wo
in its rear by which it is flanked; and from these p
at least three pieces of artillery should bring their
to bear on the ditch and scarp of the lunette.

To give the lunette greater efficiency, it
have a covered-way with a re-entering place of ar
organized in the usual way. The communication
the lunette to its covered way is across its ditch, n
the extremity of the flank, and it is covered from
in the direction of the ditch in the usual manner

The communications between works of the
and the main defences may be either open, or subter
The former will be an arrangement like a double ca
nière, leading from some point of the covered way
the work in its rear to the gorge of the detached w
A communication of this kind is objectionable from
an obstacle to the free manoeuvres of the garrison
the ground between the main defences and the de
ed-work; and, when it falls into the enemy's han
it is a cover which he may turn to profit in his a
proaches. The subterranean communication is an o
dinary gallery which leads from the ditch of one of
out works to the interior of the detached work.

It has been proposed to arrange lunette
a connected system in advance of the main defen

and in two or more concentric lines; the works on one line flanking and sweeping by their fire the rear and front of those on the line in advance. Combinations of this character would greatly increase the expense of fortifying a given position, and could be rendered serviceable only in fortresses of the largest class, with garrisons of sufficient strength to occupy the main defences and the detached works.

244. Detached works when placed, either on the path of an enemy's approaches, or on points inaccessible to him on the flank of his line of approach; or on points from which ground favorable to him, but not swept by the fire of the main defences, can be seen; or on points commanding the main defences; or if placed with a view to prevent the bombardment of a large work or to secure it from a coup-de-main, may render most important services to the main defence, by exhausting the enemy's resources in the partial operations to which he will be forced for the reduction of these works.

Under this head may be arranged open, or barbette batteries for sea-coast defence. The position and plan of these will be determined by the locality; the object in view being to prevent access to shipping at certain points. The front of these batteries are generally revetted, and they should be secured at their gorges from

a coup-de-main, when in positions where this might be attempt by a force landed in boats. A small casemated redoubt, or tower, large enough to contain a garrison for the service of the battery, arranged with loop holes for musketry, and carrying one or more guns in barbet on its top, is the best means of securing the battery fro such attacks.

Natural Features as Accessary Defences.

245. Water is one of the most obvious obstacles that may be turned to advantage against the enemy. It may be used in this way either to render portions of the enceinte inaccessible, by damming back a stream, and dro ing the ground in advance of them; or for the defence of the ditches. When, in addition to the former expedien a detached work, placed on the ground drowned, and rende inaccessible by the water, can be arranged to sweep in fla the enemy's approaches on other portions, a great acces- sion of strength will be given by it to the main defen

The most effective manner in which water ca be used in the defence of ditches is by creating a rapi current, or water-chase through them, of sufficient pow to sweep away any works the enemy may place in th This will require the construction of dams to gain a sufficient head of water for the object in view, with

sluice, or chase gates, through which the water in the reservoir may be let out. In addition to this, the site must be such that the bottoms of the ditches may receive a slope that will favor the rush of the water.

The ditches of some portions of the work may be used as reservoirs, by placing dams of masonry at suitable points across them, with one or more turning gates, or sluices in the dam through which the chase is made. These constructions should be placed at points least exposed to the enemy's projectiles, as the salients of the counterscarp; and they should be sheltered by bomb-proof arches.

For the better defence of the ditches by water, the level of the demi-lune ditch should be at least 6½ ft. above the bottom of the main ditch; so that this ditch being filled to the depth of 6 ft, the enceinte may be secured from any attempts of the enemy during the defence of the demi-lune, and the assailed may have the facility of making sorties upon the enemy's works in the demi-lune ditch. These works may be farther retarded by successive chases of water. After the fall of the demi-lune, the water may be drawn from the main ditch, to enable the assailed to make sorties on the enemy's works in it; and these works may in turn be destroyed, or damaged by a chase. These operations may be alter-

nated until the breach in the enceinte is in a state to offer but little impediment to an assault, when the main ditch should be again filled to the depth of 6 feet to secure the garrison from surprise.

In stony sites great obstacles may be placed to the enemy's progress by forming the embankments of the glacis of the loose blocks of stone, and wherever the rock crops out, or is near the surface, by removing all the loose soil that would afford him means of forming covers.

Attack and Defence of Permanent Works

French Materials.

1. Under this head are comprised the materials used by the besiegers, in the construction of the works thrown up by them, for forming revetments, and covers against the fire of the defences, of which the following are the principal.

Fascines. These are usually made 18′ long, and 9″ in diameter, and are afterwards cut into suitable lengths for the purposes to which they are to be applied.

Pickets. Those used for securing fascines are from 2′ to 4′ long, and from 1¼″ to 1¾″ thick: those for setting out, or tracing the works are 18″ long, and 1″ diameter.

Sap-fagots. These are made like fascines of straight brushwood at least 1″ in diameter. They are 2′. 9″ long, and 9″ diameter. The centre stake should be from 1½″ to 2″ in diameter, and project 9″ beyond one end of the sap-fagot; this projecting portion is sharpened, to enable the sap-fagot to be planted firmly in the ground in an upright position.

Gabions. The exterior diameter of these is 2′, and the height of watling 2′. 9″. They are made with seven, or nine stakes, which project 6″ above the watling at top, and are pointed.

Sap-rollers. This is a large gabion 7'. 6" in length, and 4'. 4" exterior diameter. It requires for its construction fifteen stakes, each from 1¼" to 2" in diameter. After it is completed it is stuffed compactly with fascines 7'. 6" long. The sap-roller is sometimes made of two concentric gabions, the diameter of the smaller 2'. 6". The space between the two is compactly stuffed with fascines.

Sand-bags. The sand-bag, for the revetment of batteries, when empty and laid flat is 2'. 8" long, and 1'. 4" wide. Those used in the construction of the trenches are 2' long and 12" wide.

Blindage-frames. These frames Pl.X.Fig.1. are composed of two uprights, or stanchions of 5" scantling, each 8'. 6" long and pointed at both ends; and two horizontal pieces of the same sized scantling each 3'. 4" long. The horizontal pieces are notched upon the stanchions at 12" from each end. The width of the frame from out to out is 3'. 4"; the distance between the horizontal pieces from out to out 6'.

An auxiliary stanchion Fig.2. with a projecting piece is used in placing the blindage frames.

Gallery frames. The arrangement and dimensions of these are the same as those used in mining.

Trenches.

2. The term Trench is applied to an excavation, or ditch made by the besiegers, by means of which and of the earth thrown from it they are enabled to obtain speedy cover from the fire of the defences, and to approach them with security.

3. Trenches are divided into two principal classes; the Parallels; and the Approaches. The parallels are designed as stations for troops to guard the trenches and the workmen employed in their execution from the sorties of the garrison. The approaches serve simply as covered communications which lead to the parallels, and towards the points of the defences upon which the attack of the besiegers is directed.

The general direction of the parallels is parallel to, or concentric with the line connecting the most salient points of that portion of the defences attacked. The approaches are run in a zig-zag, or in a straight line, upon some, or all of these points.

4. The trenches of the parallels Pl X. Figs. 3. 4. 5. 6. receive a width at bottom of 10′, ; their depth in front is 3′, and in rear 3′. 6″. Two steps each 18″ high, and 18″ wide, lead from the bottom of the trench, on the front side, to the natural ground. The reverse of the trench receives a slope of 45°; or else is also cut into

two steps. The steps in front are alone revetted with fascines. The trenches of the approaches Pl.X.Figs.7.8. are 8′ wide at bottom, 3′. 6′ deep in front, and 4′ at the rear. The reverse receives a slop of 45°. The front is usually made with a slope of 2′ base.

5. The earth from the trench is thrown to the front to form a parapet. The general height of this parapet is nearly 5′; its width at the base about 18.

6. Simple Trench. When the parapet is formed of the earth alone Figs.3.4.7. the trench is termed a Simple Trench, In this case the earth of the parapet is allowed to take its natural slope on the side towards the trench. The step, or berm of 18″ between the foot of the parapet and the trench in the parallels serves as a banquette.

Portions of the parallels Figs.4.6. from 20 to 30 yards in length are arranged with steps, revetted with fascines, leading from the trench over the parapet, to enable the troops in the parallel to débouche from it against a sortie.

The direction of the trench is laid out by pickets, connected by white tape which is marked off into lengths of 6′ by short pieces attached to it. The trench is executed by soldiers of the line; each man being furnished with a pick and shovel with which he excavates 6′ in length

of the trench, and as much of it to the rear as may be assigned to the relief or working party to which he belongs. After the trench has received its general width and depth, the slopes and steps are finished off with the assistance and under the direction of the engineer troops.

7. **Flying Sap.** When the trenches have been pushed forward to within destructive range of case shot, or from 400 to 500 yards of the defences, the construction by the simple trench has to be abandoned, and one which will afford more speedy shelter resorted to. This is effected Figs. 5.8. by placing a row of ordinary gabions in juxtaposition, along the direction of the trench; and first filling them with the earth dug up, and then completing the parapet by throwing the remaining earth over and beyond them. This process is termed the flying sap, from the rapidity with which the work is done. It also is executed by troops of the line, each man bringing two gabions on the ground, which he is required to fill, and to complete the portion of the trench in the rear of them assigned to the relief to which he belongs. The requisite height is given to the parapet either by heaping up the earth above the top of the gabions, or by placing three ordinary fascines upon the gabions, two being in the bottom course and the other on top, and throwing up the earth at least as high as the top

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The laborers for constructing both this and the simple trench are divided into three parties, or reliefs. The first digs the trench to the requisite depth and to the width of 5'. The second widens it 4'. 6". The third finishes what remains, giving the requisite slopes to the front and rear.

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side towards the defences, by the parapet of the trench, from which he débouches; and in front by a sap-roller, which is placed perpendicular to the line of direction on which he is to work, and rests against the gabion he is filling, covering it one foot. The portion of the sap which he digs is 21" wide at top, and 21" deep; it receives a slope of 4 perpendicular to 1 base on the front, and is vertical in the rear; and its length is 5'. So soon as this portion is finished № 2, who is protected in all respects like № 1, commences to widen and deepen the trench 8" at the point from which № 1 started and follows on after № 1, keeping always 5' in his rear. When № 2 has pushed forward 5', № 3 commences and enlarges the trench in each direction 7"; he follows on also 5' in rear of № 2, but as the work thrown up by the sappers preceding him affords pretty good cover, he can work standing, taking the precaution to bend forward for greater security. Finally № 4 begins when № 3 has got on 5', and deepens and widens 7". As he is well covered he can work in an unconstrained posture.

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side towards the defences, by the parapet of the trench, from which he debouches; and in front by a sap-roller, which is placed perpendicular to the line of direction on which he is to work, and rests against the gabion he is filling, covering it one foot. The portion of the sap which he digs is 21" wide at top, and 21" deep; it receives a slope of 4 perpendicular to 1 base on the front, and is vertical in the rear; and its length is 5'. So soon as this portion is finished № 2, who is protected in all respects like № 1, commences to widen and deepen the trench 8" at the point from which № 1 started and follows on after № 1, keeping always 5' in his rear. When № 2 has pushed forward 5', № 3 commences and enlarges the trench in each direction 7"; he follows on also 5' in rear of № 2, but as the work thrown up by the sappers preceding him affords pretty good cover, he can work standing, taking the precaution to bend forward for greater security. Finally № 4 begins when № 3 has got on 5', and deepens and widens 7". As he is well covered he can work in an unconstrained posture.

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The trench fascines are placed upon the gabions by the assistants; and the remainder of the trench completed by working parties of the line so soon as the brigade of sappers have proceeded far enough for the others to commence without hindrance.

9. **Double Sap**. This sap Figs.12.13 is nothing more than two heads of sap pushed forward by two brigades working abreast. Its object is to form a trench in a position exposed on both sides to fire. The heads of the sap is covered by two sap-rollers placed end to end a bag of wool, or a short sap-rollers, being placed at the junction, for additional security. The distance between the two rows of gabions is 13'. The earth between the two lines of sap is removed by the usual working parties as in the preceding case.

10. **Half Double Sap** This is an ordinary line of full sap Fig.14 pushed forward in a position where it is necessary to give temporary cover on the reverse of the trench by gabions filled with sand bags. The distance between the two rows of gabions in this case is only 5'. 6"; the single sap-roller covering in front this interval from enfilading fire.

11. **Defilement of Trenches**. The position given to the line of the parallel, and the dimensions adopted for its trench and parapet give ample cover to

the troops in it, from the plunging fire of works having any thing like the usual command. But in the zig-zag approaches, or boyaux, as the line of the trench has to be directed towards the defences, it is necessary either to defile the trench, by giving it a direction such that the fire coming over its parapet will not have a plunge sufficient to attain a man standing in the reverse of it; or, when this cannot be done, to erect traverses along the line to be covered which shall effect the proposed end.

In the usual cases of practice, the ground on which the approaches are run will be more or less uneven, and this inequality of surface, if quite appreciable, will demand a corresponding variation in the line of direction of an approach where its defilement is to be effected by the position given to it with respect to the point from which it may be attained by the enemy's fire. In most cases however, each portion of the line of the trench, corresponding to the changes in the surface, may, without any very great error, be regarded as lying either on a horizontal, or an inclined plane; and, in the latter case, the plane may either rise towards the dangerous point, or descend in the same direction; there will therefore arise three cases of defilement, according to the position of the plane on which the trench is run with respect to the dangerous point.

To allustrate these cases, let the approach to be defiled be a trench constructed with the flying sa Now, whether the ground be horizontal, or inclined, t relative positions of the lines of the profile of the appr should be preserved as nearly as practicable. The verti height of the top of the parapet, (supposing the latt no higher than the top fascine,) above the bottom o the trench at the reverse side Figs. 15 16.17 will ther be 8'.3"; and the horizontal distance between the same points 12'. Now in order that a man standing at th reverse of the trench may be secure, the line of fire the enemy should not have a greater plunge than 6'. above the bottom of the trench at this point. This wil limit the inclination of the line of fire to the horiz tal drawn through the top of the parapet, to about o perpendicular to seven base, or an angle of 1/7. It wil readily be seen from this that the line of the trench must not be run so near the dangerous point that th line of fire from it, passing through the top point o the parapet and in the direction of the profile of th trench, (that is in a vertical plane containing the dangerous point and perpendicular to the horizontal projection of the line of the trench,) shall make a greater angle than 1/7; and that when the line of t trench satisfies this condition it will be defiled by

position.

12. To find the defiled position of a trench on horizontal ground. Let D Fig. 18 be the point of departure of an approach leading from a parallel, and C the most dangerous point of the defences for this approach, the height of which above the parapet of the approach is known. It is evident, from what has just been laid down, if the approach were continued on beyond the point C, and a line with an inclination of 1/7 were drawn from C perpendicular to the direction of the approach and through the top of its parapet, that a man standing at the reverse of the bottom of the trench would not be attained by this fire; but as the top of the parapet, or interior crest of the approach is horizontal, and the reverse of the bottom of the trench is parallel to it, it is farther evident that the plane, which passes through the point C and the interior crest of the approach, will pass at the same height above every point of the reverse of the bottom of the trench that the line of 1/7 through C does above the point G, since this line lies in the plane; it therefore follows that if the point G is defiled every other point along the reverse of the trench will also be defiled. To construct the position of the line D F to satisfy this condition, describe from the point C as a centre, with a radius

equal to seven times the vertical height of C above the parapet of the approach, an arc of a circle, the tangent to this arc from D will be the required position.

Note. In Fig: 18. the dangerous point C is 18' above the horizontal plane of the trench. The reference of this plane being (0), that of the point C is (18.0), and that of the interior crest of the approach is (4.25). The ref. of the point a is (11.0); the declivity of the glacis planes 1/21.

13. To find the defiled position of an approach on inclined ground. Let Fig: 18 two planes of a glacis intersecting in a ridge a b, one of the planes running in the direction of the dangerous point C, and the other falling towards it, be taken as the ground on which the trenches are to be made; and let A at the foot of the plane which ascends towards C be the point of departure of the approach. Now the plane being produced towards C may either pass above it, through it, or below it; in either of the two first positions it is evident, if the interior crest of the approach were directed on the point C, that the trench would be defiled; for no line of fire from C would, in either of these cases, have a plunge into the trench, and the same would hold true if the plane produced passed at a distance below it just equal to the height of parapet of the approach. In either of these cases, therefore, to defile the trench, it will only be necessary

direct its interior crest on the dangerous point, and this direction may be kept until the approach strikes the ridge, At this point B it commences to descend the plane which falls towards C and a change in its direction will be requisite. To find this new direction, it will be necessary to recall that the line of fire from C, having an inclination of 1/7, which is contained in a profile plane of the approach, and passes through the top of the parapet, will pass above the head of a man standing in the trench on the reverse side; and, since the reverse line of the bottom is parallel to the interior crest, that the plane which contains this line of fire and the interior crest will pass at the same height above every point of the reverse line of the bottom, and that the trench therefore will in this position be defiled throughout. To construct this position, let the point C be taken as the vertex of a right cone the elements of which make an angle of 1/7 with its base. The line of fire of 1/7 will be an element of this cone. If the cone be intersected by a plane parallel to the one on which the approach is run, and at a distance above it equal to the height of the parapet, the interior crest of the approach must intersect the curve cut from the cone by this plane, and, to satisfy the conditions imposed, the point of intersection must be where the projection of the element of the cone is perpendicular to that of the interior crest,

as these are the relative positions in projection of the line of fire of V and of the approach. To construct the projection of the curve cut from the cone, it will only be necessary to intersect the cone and plane by equidistant horizontal planes, and to find the projections of the corresponding points of intersection of the lines cut from the two surfaces by these planes. To find the direction of the approach, join the point of its departure B with C, and on this line describe a semi circle, the point X where this semi circle cuts the projection of the curve cut from the cone will give the required direction BX of the approach.

A like construction would give the direction of an approach on an ascending plane, where the plane passes at a greater distance than the height of the parapet below the dangerous point.

14. It will be noted, from what precedes, that the approach is never directed within a dangerous point for the obvious reason that if so placed it would be exposed to reverse fire from the point. If it should happen that the direction BX, found for the approach in the preceding case, would bring its prolongation within a dangerous point C', on the left of the ridge towards which the plane ascends, it would then be necessary to change the direction BX, to that CBX',

and as this would expose the trench to a plunging fire from C, it will be farther requisite either to deepen the trench, or to raise the parapet higher, to cover the reverse from this plunge.

It will be farther noted, that at the point of departure of an approach from a parallel, there will be a portion of the parallel o p q, in the rear of the trench, which will not be fully covered by the parapet of the approach. This portion will be limited by the line of fire from C through o, where the reverse of the approach cuts the interior crest of the parallel, and the reverse prolonged to q. To secure this portion, either the trench of the parallel must be deepened, or that part of the parapet of the approach be raised which is intercepted between the lines of fire from C on p and q.

15. When the defilement cannot be effected by the position given to the trench resort must be had to traverses. Two cases present themselves under this head; one in which the reverse of the trench is exposed to a very slant fire; the other in which the trench is pushed forward between two dangerous points, and is at the same time exposed to an enfilading fire

16. In the first case Fig. 19 the trench is carried forward by means of the half-double sap. So soon as the head of the sap has been advanced the length of twelve

gabions beyond №4, a short end of sap, termed a "Wing Traverse," is commenced in a direction perpendicular to that of the trench, and run out until it intercepts the line of fire upon the point of departure at the distance of twelve gabions in its rear. When this end of sap is completed the provisional parapet in its rear can be taken down and the trench enlarged to its proper width. In this way the trench is successively pushed forward and enlarged, until a position has been reached where it becomes necessary to place a traverse to cover the trench from both enfilading and reverse views. These traverses A,A are made by changing the direction of the trench perpendicular to that of the original line, and continuing in this new direction by the full sap the requisite length of the traverse; the original direction is then resumed, and continued by the half double sap, a sufficient distance to leave room for the width of the traverse and a trench of double sap; another rectangular turn is then made by the double sap back to the line of gabions of the original trench, and the original direction is again taken up and carried forward by the half double sap.

The traverses A,A are seven gabions or about 14' in width. Their length will depend on the positi

of the dangerous point, but they are seldom made over 30 in length. Their distance apart will also depend on the command of the dangerous point. The portion of trench between any two traverses must be perfectly covered by the advanced traverse. As a practical rule the traverses are not placed farther than 25 or 30 yards apart.

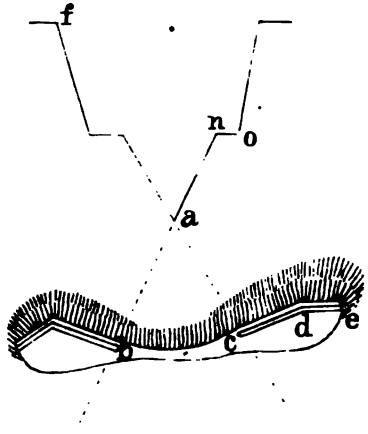
The portion of the trench B in rear of the end of the traverse is covered by extending sufficiently far to the rear of it an end of trench C, forming a wing traverse, to intercept the line of slant fire.

17 In the second case Fig. 20 the trench A is carried forward by the double sap until the point of departure B is about being exposed to the fire coming in over the sap-rollers; a change of direction C at right angles is then made by the full sap, to the right or left, and pushed forward the length of about fifteen gabions when the original direction D by the double sap is resumed. A change of direction is somtimes made both to the right and left at right angles to the original direction, by the full sap, and pushed to the length of twelve or fourteen gabions. Then, from the extremities of these branches, a direction parallel to the original is taken up by the double sap, and pushed on until the point of departure is about being exposed, when a change of direction is

made at right angles by the full sap and the two branches are united on the original direction E, which is resumed by the double sap.

Trench Cavalier.

18. This work consists of a parapet raised on a mound of earth for the purpose of obtaining a plunging fire on the covered way. The mound should in all cases be raised so high that the cavalier will have a command of 4¼ feet over the crest of the covered way. The position of the cavalier is shown in the annexed Fig. When the trenches are advanced by the full sap nearly within reach of grenades thrown by hand, or about 30 yards from the salient a of the covered way, a circular portion of trench b c is formed, to embrace the production of the crests of the salient; from the extremities of this circular portion the sap is run perpendicular to the direction of the crests, to a distance c d of about 8 or 12 yards, so as to enfilade the covered way; at the extremity d, a wing, or return d e is made, to cover the part c d from the flank and reverse fire of the collateral works; this part d e may, in some cases, be



arranged nearly parallel to the crotchets n o of the covered way, so as to give a fire on them; but generally it serves only to cover the branch c d as has been explained.

19 There are two ways of forming the cavalier, depending on the nature of the soil. When the excavated earth is of such a nature that it can be easily made to stand at any slope, a profile represented by Fig. 21 is preferred, as requiring less time and materials. After having laid out the position of the cavalier by the full sap, the sappers widen the trench 6 feet, and make a step at the bottom of the trench 22" in height, and 5'6" within the gabion of the parapet; this step serves as a platform on which the sappers mount to level the earth of the parapet even with the facines on top of the first gabion, for the purpose of placing a second tier of gabions, which is placed 22" beyond the first. This second tier is filled with earth, and crowned with two fascines, and the mound is raised to a level with the fascines, by widening the trench to the rear. The earth is now levelled even with the top of the fascines, and a third tier of gabions is placed just on the outside of the second, it is filled with earth crowned with three fascines, and the mound is raised to a level with the upper fascine. This top tier forms the parapet of the work. Loop holes are made, by arranging sand

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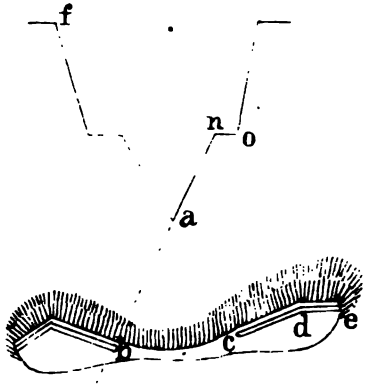

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19 There are two ways of forming the cavalier, depending on the nature of the soil. When the excavated earth is of such a nature that it can be easily made to stand at any slope, a profile represented by Fig. 21 is preferred, as requiring less time and materials. After having laid out the position of the cavalier by the full sap, the sappers widen the trench 6 feet, and make a step at the bottom of the trench 22" in height, and 5'6" within the gabion of the parapet; this step serves as a platform on which the sappers mount to level the earth of the parapet even with the facines on top of the first gabion, for the purpose of placing a second tier of gabions, which is placed 22" beyond the first. This second tier is filled with earth, and crowned with two fascines, and the mound is raised to a level with the fascines, by widening the trench to the rear. The earth is now levelled even with the top of the fascines, and a third tier of gabions is placed just on the outside of the second, it is filled with earth crowned with three fascines, and the mound is raised to a level with the upper fascine. This top tier forms the parapet of the work. Loop holes are made, by arranging sand

bags on top of the parapet, for the purpose of covering the heads of the men whilst in the act of firing. As the successive tiers of gabions are placed, steps, revetted with fascines, are made to lead to the top; these steps have a rise and tread of 22" inches, the top one, serves as a banquette.

20. When the soil excavated is loose, a cavalier made in the manner just described would not be sufficiently firm. The following construction will in this case be used. After having laid out the cavalier by the full sap, a row of gabions Fig. 22. is placed in the bottom of the trench, along the foot of the interior slope; this row is filled with earth, and crowned with two fascines, and earth is filled in between it and the interior slope and brought to a level with the berm. A third tier of gabions is placed on this platform along side of the row forming the parapet of the trench, this tier is, in like manner, filled with earth, and crowned with two fascines. The second tier of the cavalier is commenced, by placing a fourth row of gabions over the joint of the two in the first tier; this is filled with earth, crowned with two fascines, and the mound is raised on the exterior to a level with this fourth gabion. A fifth row is next placed along side of the two in the first tier, filled with earth and crowned with two fascines. A sixth is then placed

along side of the fourth, in the second tier, and arranged like the preceding. Finally the parapet is formed on this second tier, by placing a gabion above the joint between those of the second tier and arranging it as in Fig. 17. The steps are made to ascend to the top, by throwning up a mound of earth on the interior against the gabionade, and forming the surface into steps revetted with fascines as in the last case.

Descents of the Covered-Way and Ditches.

21 **Blinded Descent.** When a trench has to be pushed forward in a position where the command of the dangerous point is so great that it cannot be sheltered from the plunging fire by traverses, it is covered on the top, and on the sides by fascines and earth supported by a frame work, and is termed a Blindage.

This method of obtaining cover is principally requisite in trenches which descend towards the dangerous point; like the passages which lead from the trenches on the glacis into the covered way, and to the bottom of shallow ditches. The manner of forming the blindage Figs. 23, 24 is to set up a row of blindage frames along each side of the trench, or passage; to connect the two rows at top by like frames laid across the line of the trench; to cover the top frames by fas-

-cines and earth; and to fill in between the side frames and the sides of the trench with fascines. The trench is made by the double sap. Its width at bottom is 7'.6". The width between the frames 6'. The frames and fascines of the blindage are gradually placed as the trench advances, the latter preceding the former about 5'. The work is begun by placing an upright frame on each side, the two are next connected by a frame on top, one side of which is lodged on the top cross pieces of the upright frames, and the other supported by two auxiliary frames until the next two upright frames are placed; the fascines are then thrown over the top frame to the depth of about 2', and these are covered with earth, or raw hides, to prevent their being set on fire. Fascines are at the same time placed in on the sides.

The slope given to the bottom of a blinded descent should not be greater than 1/4. When the descent is to a covered way Figs 23.24 the bottom of it should debouche into the covered way at 43" below its terre-plein this will serve to determine the point of departure, the slope being fixed, which should be 5' below the surface of the glacis, so that when the blindage is put up at this point the top of it shall not be above the level of the parapet of the trench. A horizontal lan

ing about 8' in breadth is made at the entrance of the blindage; and this is connected with the bottom of the trench by two ramps of 1/6.

The point selected for a blinded descent into a covered-way is usually at the end of a traverse; as the traverse will cover the outlet of the blindage from a plunging fire in front.

22. A descent to a ditch is usually by blindage when the depth of the ditch does not exceed 10' or 12'. For greater depths the commencement of the descent is by a blindage, Fig. 25 which is continued to a point where the bottom of the descent is about 9' below the surface of the ground; here the blindage is terminated, and the remainder of the descent is made by gallery, as the depth of earth above the gallery will be sufficient to allow the excavation to be carried on without trouble. In a firm soil, grand gallery frames are used for the descent; in a loose soil common gallery frames. The construction of the gallery is the same as for a mine gallery.

The point of departure of a ditch descent is usually taken at only about 2' below the bottom of the trench; the usual landing being made at this point. In a dry ditch the bottom of the descent debouches at the usual depth of the full sap below the bottom of the

ditch. In a wet ditch it should come out about 15" above the water level.

Passages of Ditches.

23. The passage of a dry ditch is nothing more than a full sap which leads from the outlet of the descent to the ditch to the bottom of the breach. From this point the trench and parapet are directed up the breach to the scarp wall which forms the side of the breach towards the dangerous point. The only precaution necessary in making this passage is to sink the trench at the outset to its full depth of 43" to gain secure cover.

24. The passage of a wet ditch is a perilous and difficult operation under any circumstances, but particularly so when a strong current can be produced by the besieged in the ditch. The methods usually recommended are to form a dike, or bridge of fascines and hurdles, laid in successive layers, and firmly connected by pickets. To form a footing for the dike, a grand gallery is excavated, directly behind the counterscarp wall, to a distance of 12' or 15' on each side of the descent, and the earth from it is thrown into the ditch through the outlet of the descent. The dike or bridge of fascines, is gradually pushed forward from this point, being secured in the best way practicable to

the earth thrown into the ditch. The sappers who carry forward the head of the duke are covered from the fire of the dangerous point by a musket proof mask of fascines and boards attached to a raft on which they work. The duke should be from 12′ to 15′ wide at top. A gabionade parapet is placed on it towards the dangerous side. It is formed of two tiers of gabions, filled with earth. The bottom one consists of two rows of gabions each crowned with two fascines, the two rows being in juxtaposition; the top tier is a single row crowned with three fascines. The top of duke is covered by a layer of earth, and the parapet with raw hides, to prevent the effects of incendiary compositions that might be thrown on them.

Raft bridges on barrels, protected by a gabionade parapet, have also been proposed, particularly where a strong current is to be contended with.

Batteries.

25. Enfilading and Counter-Batteries. These batteries are used for destroying the artillery and silencing the fire of the defences. Positions are chosen for the first from which the terre-pleins of the faces, that bear upon the ground on which the parallels and approaches are laid out, can be enfiladed; the second are so placed that they can bring a direct,

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26. As the effects of both direct and enfilading fire vary greatly with the range, positions should be chosen for these batteries as near the defences as they can be thrown up without too great a sacrifice of life. Positions which will give ranges between 300 yds and 700 yds are the best; nearer than 300 yds the workmen would be exposed both to the fire of musketry and case shot; beyond 700 yds the fire upon the defences becomes very uncertain. The best points for these batteries are therefore on the zone of ground occupied by the 1st and 2nd parallels; the former being at about 600 yds and the latter about 300 yds from the most salient points of the defences.

27. The batteries may be placed either within the parallel, in advance of, or in the rear of it. The positions usually selected are from 20 yds to 30 yds in front of the parallel; because if placed within it, there might be mutual interference between the services of the batteries and that of the parallel; and unless

placed at some distance in the rear of it, the parapet of the parallel might obstruct the shot of the battery, and the troops in the trench be annoyed by the fire.

28. The most effective positions for these batteries are in front of the 2nd parallel; and unless the fire of the defences is very destructive it will be best to place them there. If placed in front of the 1st parallel it will be necessary to shift the most of them to the front of the 2nd parallel soon after the latter is thrown up. For the 3d parallel and the approaches leading to it from the 2nd parallel run the risk of being attained by shot from batteries at so great a distance in their rear as the 1st parallel.

29. The site of the platforms of the batteries may either be on the surface of the natural ground, or sunk below it. In the latter case the battery is termed a Sunken Battery. In the former case the parapet of the battery is obtained from a ditch in advance of it; in the latter it is got from the trench in its rear. In the sunken battery the labor of construction is less, and the men engaged in making it are placed more speedily under cover than in the other kind. Sunken batteries can only be

used however when the trenches, or other elevated points in advance of the batteries, which lie in their field of fire, will not intercept the shot, and as a general rule, these batteries should be placed only in positions where their field of fire is completely unobstructed by the trenches.

30. The interior crest of an enfilading battery should be nearly perpendicular to the prolongation of the line to be enfiladed; and be so placed that the shot from all the guns shall sweep the terre plein throughout its entire length. The position of a battery that will satisfy this last condition can be readily found, as it must evidently lie within the angle formed by producing to the exterior the diagonals of the terre-plein to be swept. The best position for the guns will be to place one so that its line of fire shall be nearly on the prolongation of the interior crest of the line enfiladed, and the remainder on that side of this one on which the exterior line of the terre-plein prolonged may fall.

31. In a counter-battery the interior crest should be nearly parallel to the line to be counter battered. A position somewhat oblique to the line, so that the shot of the battery may enter the embrasures obliquely, is also a good one for tearing away

the cheeks of the embrasures, and exposing the guns of the defences.

32. Whenever a position has to be taken up for an enfilading or a counter battery in which the direction that can be given to the interior crest is very oblique to that which it ought to receive, it will be necessary to make the embrasures of the battery with a corresponding obliquity to the direction of the parapet, and, to avoid the inconvenience of these last, it will be farther necessary to break the interior crest into an indented line, to allow the muzzles of the guns to be run the requisite distance into the embrasures; placing one side of the indent perpendicular to the axis of the embrasure, and the other parallel to it.

33. Enfilading and counter-batteries are usually armed with 18 and 24 pounders, and 8 inch howitzers. The fire of the guns is mainly directed to destroy the artillery of the defences; that of the howitzers to sweep the covered ways and ditches, to destroy the palisadings, and injure the traverses by the explosions of the shells that may lodge in them. As a general rule there need not be more than seven pieces, nor should there usually be less than three in any one battery; the number depending

bags on top of the parapet, for the purpose of covering the heads of the men whilst in the act of firing. As the successive tiers of gabions are placed, steps, revetted with fascines, are made to lead to the top; these steps have a rise and tread of 22" inches, the top one, serves as a banquette.

20. When the soil excavated is loose, a cavalier made in the manner just described would not be sufficiently firm. The following construction will in this case be used. After having laid out the cavalier by the full sap, a row of gabions Fig. 22. is placed in the bottom of the trench, along the foot of the interior slope; this row is filled with earth, and crowned with two fascines, and earth is filled in between it and the interior slope and brought to a level with the berm. A third tier of gabions is placed on this platform along side of the row forming the parapet of the trench, this tier is, in like manner, filled with earth, and crowned with two fascines. The second tier of the cavalier is commenced, by placing a fourth row of gabions over the joint of the two in the first tier; this is filled with earth, crowned with two fascines, and the mound is raised on the exterior to a level with this fourth gabion. A fifth row is next placed along side of the two in the first tier, filled with earth and crowned with two fascines. A sixth is then place

along side of the fourth, in the second tier, and arranged like the preceding. Finally the parapet is formed on this second tier, by placing a gabion above the joint between those of the second tier and arranging it as in Fig. 17. The steps are made to ascend to the top, by throwning up a mound of earth on the interior against the gabionade, and forming the surface into steps revetted with fascines as in the last case.

Descents of the Covered-Way and Ditches.

21 **Blinded Descent.** When a trench has to be pushed forward in a position where the command of the dangerous point is so great that it cannot be sheltered from the plunging fire by traverses, it is covered on the top, and on the sides by fascines and earth supported by a frame work, and is termed a Blindage.

This method of obtaining cover is principally requisite in trenches which descend towards the dangerous point, like the passages which lead from the trenches on the glacis into the covered way, and to the bottom of shallow ditches. The manner of forming the blindage Figs. 23, 24 is to set up a row of blindage frames along each side of the trench, or passage; to connect the two rows at top by like frames laid across the line of the trench; to cover the top frames by fas-

-cines and earth; and to fill in between the side frames and the sides of the trench with fascines. The trench is made by the double sap. Its width at bottom is 7'.6". The width between the frames 6'. The frames and fascines of the blindage are gradually placed as the trench advances, the latter preceding the former about 5'. The work is begun by placing an upright frame on each side, the two are next connected by a frame on top, one side of which is lodged on the top cross pieces of the upright frames, and the other supported by two auxiliary frames until the next two upright frames are placed; the fascines are then thrown over the top frame to the depth of about 2', and these are covered with earth, or raw hides, to prevent their being set on fire. Fascines are at the same time placed in on the sides.

The slope given to the bottom of a blinded descent should not be greater than ¼. When the descent is to a covered way Figs 23.24 the bottom of it should debouche into the covered way at 43" below its terre-plein this will serve to determine the point of departure, the slope being fixed, which should be 5' below the surface of the glacis, so that when the blindage is put up at this point the top of it shall not be above the level of the parapet of the trench. A horizontal lan-

-ing about 8' in breadth is made at the entrance of the blindage; and this is connected with the bottom of the trench by two ramps of 1/6.

The point selected for a blinded descent into a covered-way is usually at the end of a traverse; as the traverse will cover the outlet of the blindage from a plunging fire in front.

22. A descent to a ditch is usually by blindage when the depth of the ditch does not exceed 10' or 12'. For greater depths the commencement of the descent is by a blindage, Fig 25 which is continued to a point where the bottom of the descent is about 9' below the surface of the ground; here the blindage is terminated, and the remainder of the descent is made by gallery, as the depth of earth above the gallery will be sufficient to allow the excavation to be carried on without trouble. In a firm soil, grand gallery frames are used for the descent; in a loose soil common gallery frames. The construction of the gallery is the same as for a mine gallery.

The point of departure of a ditch descent is usually taken at only about 2' below the bottom of the trench; the usual landing being made at this point. In a dry ditch the bottom of the descent debouches at the usual depth of the full sap below the bottom of the

ditch. In a wet ditch it should come out about 15' above the water level.

Passages of Ditches.

23. The passage of a dry ditch is nothing m than a full sap which leads from the outlet of t descent to the ditch to the bottom of the breach. O this point the trench and parapet are directed on the breach to the scarp wall which forms the side of the towards the dangerous point. The only precaution sary in making this passage is to sink the trench the outset to its full depth of 43' to gain secure com

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32. Whenever a position has to be taken up for an enfilading or a counter battery in which the direction that can be given to the interior crest is very oblique to that which it ought to receive, it will be necessary to make the embrasures of the battery with a corresponding obliquity to the direction of the parapet, and, to avoid the inconvenience of these last, it will be farther necessary to break the interior crest into an indented line, to allow the muzzles of the guns to be run the requisite distance into the embrasures; placing one side of the indent perpendicular to the axis of the embrasure, and the other parallel to it.

33. Enfilading and counter-batteries are usually armed with 18 and 24 pounders, and 8 inch howitzers. The fire of the guns is mainly directed to destroy the artillery of the defences; that of the howitzers to sweep the covered ways and ditches, to destroy the palisadings, and injure the traverses by the explosions of the shells that may lodge in them. As a general rule there need not be more than seven pieces, nor should there usually be less than three in any one battery; the number depending

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to be silenced may have upon the ground on w
the works of the besiegers must be placed. The b
teries should be as far asunder as practicable,
as not to invite a concentration of the fire of th
defences upon any point, by the accumulation
of a large number of pieces on it, and thus mu
ply the chances of loss both to the troops and ma
terial.

34. In computing the extent of front of a
tery, Pl. XI Fig: 26 an allowance of 18', estimated along
the interior crest, is made for each piece, and 6' for each
splinter-proof gabionade traverse, one of which is place
between every two guns when there are more than two
in a battery. The flanks of the guns are covered by an
epaulment thrown up on one, or both extremities of
the parapet. The length of the epaulment, measured
along its interior crest, may be from 20' to 30'. The
direction of the epaulment with respect to the parap
will depend on that of the fire of the defences; as a
general rule the interior crest of the epaulment shou
make an angle of about 100° with that of the parap
When the platforms are on the natural surface, th
earth for the parapet, epaulments and traverses i
taken from a ditch in front of the parapet and ap

ments, and parallel to their respective directions. A narrow ramp, at the end of each epaulment, leads from the natural level to the bottom of the ditch, and serves for the convenience of the men whilst throwing up the battery. A trench of the ordinary dimensions of an approach and defiled from dangerous points leads from each extremity of the battery to the parallel in its rear.

If the embrasures are so oblique as to require an indented parapet, the side or face of the indent, through which the embrasure is pierced, should be 22', and the perpendicular to the axis of the embrasure. The other side, or flank of the indent should be 25, and parallel to the axis; a distance of only 7' being left between these two last lines, to give all the thickness practicable to the portion of the merlon that forms the outer angle of the indent; for a like reason the face of the indent at the extremity of the battery should extend 21' beyond the axis of the embrasure. These data will serve to estimate the total length of the parapet. Its thickness estimated from the inner angles of the indents is 18'.

35. The profile of a battery will depend both for its dimensions and form on the command of the point from which it can be attained, and on the

position of the surface of the ground, on which it
laid out, with respect to the defences.

Where the site of the battery is horizonta
and the command of the defences over it is within
the usual limits of 20′ to 30′, the following form
and dimensions Fig. 27 will afford ample cover to t
men and material of the battery, when the plat
are on a level with the natural surface. Height of
terior crest 7′. 6″. Thickness of parapet 18′ Interior sl
4/1. Superior slope 1/2. Exterior slope the natural
slope of the earth. The same dimensions and for
may be given to the epaulments, except the dista
between their interior and exterior crests, which ma
be reduced to 12′ when the direction of the epaulm
is quite oblique to that of the fire of the defences.
the contrary case this distance should be 18′. The
depth of the ditch is taken at 5′; its width will
regulated by the quantity of earth to be furnishe
for completing all the parts of the battery.

36. The axes of the embrasures Fig. 26 are 18
apart, except at the points where splinter proof tra
es are placed, the requisite distance at these points
being 24′, allowing 6′ for the width of the base of
the traverse. The sill of the embrasure is 3′. 6″ ab
the platform for guns mounted on the ordinary

siege carriage; its sole is parallel to the superior slope. The mouth of the embrasure is of a trapezoidal form, being 2' wide at bottom, and 3' at top. The splay of sole is obtained by giving the sides an inclination of 1/10 with the axis. The top line of the cheek is obtained by setting off along the direction of the exterior crest, from the point where the side of the sole cuts it in projection, one half the vertical distance between these two last lines, and joining the point thus found with the exterior point of the mouth at top.

Embrasures of howitzers may receive a counterslope, giving the sole nearly the same inclination, from the sill upwards, as the least angle of elevation under which it may be required to aim the piece.

37 The parapet of the battery and the embrasures are revetted either with gabions, fascines, or sand-bags; or with a combination of these.

The epaulments need not be revetted their interior slopes being made as steep as the earth will stand at. The gabion revetment is the firmest and most durable. When used for the parapet two tiers will be requisite.

The requisite slope is given to the gabions of the first tier by placing a row of fascines under

them, along the foot of the interior slope. Another row of fascines is laid on top of the tier, along the interior slope, on which the gabions of the second tier rest. The requisite height is given to the parapet either by placing sods on the top tier, or by earth alone. When sand-bags are used they are laid in single courses along the interior slope, and as headers and stretchers; the courses breaking joint. To give the bags greater durability they should be impregnated with tar before being filled.

It has been found that raw hides will preserve the revetments of the cheeks from the effects of the concussion produced by the firing. For this purpose the hide is folded with the hair inwards. It is confined to the top of the cheek by pickets driven through it into the merlon; and at the mouth and the other end of the cheek by pickets driven into the revetment. The lower end is allowed to hang loose.

38. The splinter-proof traverses Fig. 28 are formed of two tiers of gabions. The lower tier consists of two parallel rows of gabions and is 5′ wide at the base; the rows of gabions are slightly inclined towards each other at top. The upper tier also consists of two rows which rest on two rows of fascines laid on the first tier, the gabions leaning against each other

at top. The gabions and the space between them are well filled in with earth which is heaped above the top tier. The traverse may be from 15′ to 18′ long. A passage way of 2′ is left between the parapet of the battery and the end of traverse.

39. The platforms are 10′. 6″ wide, 15′ long in the clear, and receive an upward slope of 7″ to 8″ from the heurter to the tail. They are composed of 5 sleepers, each 15′ long and 5″ on the side; of 12 planks, each 10′. 6″ long and 2″ thick; of 2 ribands, or side rails of the dimensions of the sleepers; and of a heurter. The sleepers are firmly imbedded in the ground and secured by stout pickets at their ends. The planks are clamped between the side-rails and outide sleepers, these pieces being connected firmly either by screw-bolts and nuts, or by rack-lashings.

40. In sunken batteries the same length of interior crest is allowed for each gun as in the preceding case; but when the battery requires splinter-proof traverses an allowance of 26′ is made for the distance between the axes of the guns separated by a traverse. The position and length of the epaulments are also determined as in the preceding case.

41. The trench of the battery Fig. 29. when first

excavated is 16' wide at bottom, 3' deep in front, and 2'. 6" deep in rear. The front is cut down vertically in firm soil, and the reverse receives a slope of 1/2. The interior crest of the parapet is 4'. 6" above the natural surface; the parapet 18' thick; the interior slope 3/1; the exterior slope 1/1. A berm of 18" is left between the parapet and trench when first excavated.

42. As the dimensions above given to the trench will furnish earth only for the parapet, that required for the epaulment is taken from a ditch 5' deep exterior to it; and a small portion of ditch is made exterior to the parapet, and opposite the position of each splinter-proof traverse, to provide for the earth requisite for the traverse and which is taken from the trench. The epaulment if exposed only to an oblique fire need not be thicker than 12.

43. The embrasures receive the same form, dimensions, &c as in the preceding case.

44. The front of the trench is revetted with fascines. To put up this revetment the trench is widenened by cutting away the front nearly to the width of the berm and almost vertically. This will admit the muzzles of the guns to be run well into the embrasures.

To avoid the labor and expense of revetment

it has been proposed neither to revet the portion of the trench bordering the epaulment, nor the interior slope of the epaulment; but to leave a berm at this part, 3′ wide, when the trench is in course of construction, and afterwards to give both to this portion of the trench and the interior of the epaulment as great a slope as the earth will stand well under.

45. When splinter proof traverses are requisite, a portion of the ground 6′ wide, on which the traverse is to stand, is left. The traverse is made by first placing two parallel rows of fascines at 5′ apart, on which a tier of gabions, also of two rows, rests; the gabions being so inclined as to touch at top. Earth is filled in the gabions and the void space between them, and heaped up above them to the same level as the interior crest. The sides of the trench bordering the traverse are cut to a suitable slope and revetted with fascines. A passage of 2′ is left between the gabionade of the traverse and the interior slope of the parapet.

46. To provide against rainy weather, two or more holes should be dug at such points of the trench of the battery as may be found most convenient to receive the water that collects in the trench; and precautions should be taken to prevent water from

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46. To provide against rainy weather, two or more holes should be dug at such points of the trench of the battery as may be found most convenient to receive the water that collects in the trench; and precautions should be taken to prevent water from

being received into the trench either through the trenches leading to it, or from the natural surface

47. The powder magazines should be at least 30′ in rear of the parapet of the battery. The ceiling of the magazine should not be more than a few inches above the natural level. The interior height need not be more than 5′. The width may be 6′ and the length 12′ in the clear. The sides of the magazine may be formed of frames and sheeting boards, or of a row of gabions crowned with two courses of fascines. The magazine is covered at top by splinter-proof timbers 6″ × 9″, laid in juxtaposition and covered with at least 3′ of earth, both on top and on the sides towards the parapet and epaulments. A passage leads into the magazine on the side from the parapet, which is reached by one or two inclined trenches.

48 **Mortar-Batteries.** There are two kinds of mortar batteries used in the attack; those for mortars throwing shells; and those for mortars throwing baskets of stones, or other like projectiles. Besides these there is the Cochorn mortar which, from its small size, may be placed in any unocupied corner of the trenches. The first kind of batteries may be in front of the 1st and 2nd parallels, or on any

other points farther back. The positions chosen for them should be such as to bring as great a portion of the defences under the direction of their fire as practicable, to increase the chances of destructibility of each shell thrown. The second kind are placed in front of the 3d parallel mainly with a view to annoy the covered ways and parts adjacent.

49. The platforms of these batteries may be laid on the natural surface, in which case the same forms and dimensions will be given to the parapet and epaulments of the battery as in gun batteries; but as the mortars must be set back from the parapet, to enable the shell to clear the interior crest by about 3', a revetment will not be necessary, and the parapet may receive as great an interior slope as the earth can be made to stand under firmly.

50. The front of a mortar battery is estimated by allowing 15' for each mortar, and 6' for each splinter-proof traverse.

These batteries are however usually sunk below the natural surface, since several feet difference of level in the position of a mortar will have but little effect on the range, or the trajectory. The profile suitable for such positions under ordinary circumstances is the following. Width of trench at

bottom 13'. 6". Depth in front 3'. 6". Depth in rear 4'. Reverse slope 1/2. Front slope 2' base. Height of parapet 4'. Thickness of parapet 18'. Berm 1'.

51. The earth for the epaulment is taken from an exterior ditch; and when splinter-proof traverses are required portions of ditches are made opposite to their position to furnish the requisite earth.

52. The platforms of mortars are 7'. 6" long by 6'. 6" wide. They are composed of 2 ground-sills 7'. 6" long, and 6" square; 5 sleepers 7'. 6" long, and 6" square; 2 side-rails 7'. 6" long and 4" square; 8 planks each 6'. 6" long, and 4" thick. The ground-sills are laid horizontally, and firmly embedded in the ground at 4'. 6" apart, and transversely to the sleepers. Upon these the sleepers rest, each being confined by two stout pickets near each end. The planks are confined to the sleepers in the same manner as in gun platforms.

53. Breach Batteries Exposed revetments may be breached by heavy guns at ranges from 400 to 600 yds, and batteries thrown up in such cases are in all respects like those for enfilading, or counter-battering.

54. Where the revetments are covered from distant fire by the crest of the covered way, the breach

batteries must be either placed on the glacis, or on the terre-pleins of the defences, at points where no obstruction will intervene to prevent the fire of the guns from being directed at a point of the wall to be opened low enough to form a breach practicable to the ascent of an assaulting column.

In either of the latter cases the batteries must be sunk; the level chosen for the platforms being such as to subserve the object in view. The embrasures in these cases are usually cut out of the parapet, as an ordinary trench has generally to be first established as a preparatory step to commencing the battery. The forms and dimensions adopted for other sunken batteries will apply to these cases, with such modifications as may be demanded by the site of the battery, and the position of the point to be attained by the fire.

55. When a breach battery is established either on the glacis, or upon the terre-plein of a work, its guns will generally be exposed both on their flank and rear to the fire of dangerous commanding points, from which it will be necessary to cover them by traverses. The number of traverses and their position will depend upon the command and position of the dangerous points. To cover from the flank fire, if the command of the dangerous point is considerable,

like that of a cavalier retrenchment, it may be necessary to place a traverse between every two guns, or even between each. The traverses used in such cases receive a thickness of 14', or seven gabions, like those for covering an ordinary trench from an enfilading fire; their length will depend upon the relative positions of the dangerous point and the exterior point of the battery to be covered; their height is usually not greater than the traverses for a trench.

When the reverse of the battery is exposed it will generally arise from the salient position of some comparatively distant point, from which a slant fire may be brought to bear on this part of the battery; in which case it will generally be easy to cover the part exposed by running out, from the reverse of the battery, an end of trench, to form a wing traverse that shall intersect the lines of fire of the point upon every part exposed.

56. The guns of breach batteries should be so placed that the direction of their fire may be as nearly perpendicular as practicable to the line of wall to be breached; and where these lines are oblique to each other the obliquity should not exceed 45°; otherwise the effect of the shot will be greatly diminished and the operation retarded.

Besides the breach batteries it will be necessary to place counter-batteries on the glacis. Their object will be to counter-batter and silence the artillery of those portions of the defences which can be brought to bear on the breach batteries, or on the passages of the ditches. These batteries will usually be placed on the prolongation of the ditches of the defences. Their arrangement will be in all respects the same as that of the breach batteries.

Siege Operations.

57. The operation of a siege are usually divided into three epochs. In the first are comprised the investment and other operations preliminary to breaking ground against the work, or opening the trenches. The second comprises the labors from the opening of the trenches to the completion of the 3d parallel. The third the subsequent operations to the reduction of the work.

1st Period.

58. Investment. This is the first active operation of the besieging force; its object being to cut off all communication between the garrison and the exterior, to prevent succors of every kind from being

thrown into the work, to sweep off every thing in its vicinity that might in any way be serviceable to the garrison, and finally to cover a close reconnaissance of the defences by engineer and other officers.

For the successful attainment of these ends the investing force, which is mainly if not solely composed of cavalry, should move upon the work with celerity and secrecy, and after surrounding it and securing all avenues to it, should send out detachments to scour the environs up to the very gates of the work if practicable, and bring off with them or destroy all persons, cattle, provisions &c met with. A chain of posts and sentinels is in the mean time established in the best positions to prevent all access to the work, or egress from it; care being taken to select for the posts points which are not exposed to the artillery of the work, or are beyond its range. The posts occupied by the troops during the day-time, and termed the Daily Cordon, are shifted at dark, and points nearer the work are taken up, to form the Nightly Cordon and hem it in more closely. The posts and sentinels for this purpose should be pushed as far forward as they can find shelter from the musketry of the defences; and under the protection the reconnoitring officers should spa

no efforts to gain an exact idea of all the ground exterior to the work, and of the character of the defences.

59. Posting Besieging Force. The main body of the besieging army, with the engineer and artillery, siege trains, follows closely upon the investing corps, to prevent the line taken up by the latter, which from its extent is necessarily weak, from being forced either by the garrison, or by strong detachments from without. The positions for the camps of the various corps are designated by the commanding general after a careful reconnaissance. These are placed beyond the range of the heavy artillery of the work, with their color fronts facing from the work; and, as far as practicable, on points favorable to the health and comfort of the troops, and the defence. Whenever natural obstacles occur between the camps they must be crossed by good lines of communication, so that no impediment may be offered to the speedy concentration of the troops upon any point threatened from without.

Besides the positions taken up for the camps, the besieging force will also occupy all points exterior to the camps, within cannon range, by which they are commanded, securing them by

field works of sufficient strength to subserve the end in view.

60. Entrenchments of Camps. The front and the rear of camps are also secured by lines of field works. The exterior works termed the Line of Circumvallation, should form an unbroken line of entrenchments composed of the most simple elementary parts, as tenailles, redans &c., with a slight profile, the chief object being to prevent succors of small detachments from slipping into the place. The interior line termed the Line of Countervallation is composed of detached works which if the garrison is strong should be in defensive relations. The main points which should be occupied by these works are the principal avenues to the defences, and the positions selected for the parks of the siege trains; to secure these points from the attempts of the garrison, and to render the entrance of large convoys into the defences impracticable.

These lines are placed about 200 yards in front and rear of the camps

61. In the later sieges in Europe lines of circumvallation particularly were seldom resorted to; the besiegers contenting themselves with occupying only the main points of their position by field

works, and giving the intervening space such protection as could be afforded by strong patroles and posts. This departure from former practice arose in most cases from the want of strength of the besieging force, and was frequently attended by the very events against which lines are chiefly effectual in guarding. As a field of battle against a succoring force of sufficient strength to cope with the besieging army, a position taken behind a line of circumvallation is, but in rare exceptions, eligible, a maxim that applies to all extended and weak lines; and in almost every case where a serious effort has been made against such positions it has proved successful, and has entailed heavy losses on the besiegers. But it must be repeated as this is not the object of these lines they are not open to this objection; and as they have been found serviceable for the sole purpose to which they should be applied they ought to be thrown up in all cases where the means of the besiegers will admit of it.

62. Preparations for Opening the Trenches. Whilst the besieging force is occupied in arranging and securing their camps, a portion of it is employed in preparing the trench materials, establishing the parks, and getting every thing in order pre-

paratory to breaking ground against the defences. At the same time close reconnaissances and careful instrumental surveys are made by the staff corps, to obtain data for a map of the defences and their environs, with a view of drawing up a plan of attack. With this object the bearing and prolongation of the faces and capitals of all the defences should be carefully laid down; the character of the defences on every assailable point noted; that of the parts bearing on these points; and the nature of the ground over which they must be approached.

63. The parks, magazines of powder and other depots are placed on the most secure points, beyond the range of the heavy artillery of the defences, and if practicable be hidden from their view. The points selected, if not in the immediate neighborhood of the ground on which it is decided to open the trenches, should have avenues of easy access to it, for the transportation of whatever may be requisite in carrying forward the works of attack.

64. Point of Attack. After obtaining all the information that can be had from the reconnaissances, surveys and other sources, the next object is to decide upon the portion of the defences

which it will be necessary to gain possession of to force the garrison to a surrender; this portion, usually embracing one or more fronts of the enceinte with their outworks, and any advanced works that may be connected with them and must be reduced before they can be assailed, is termed the Point of Attack. It is in the choice of this point, a decision which mainly rests with the commanding officer of the engineers, that the judgmend and skill of this officer are shown. In making this selection he must carefully weigh not only the relative strength of the various points of the defences which are accessible, but the character of the site upon which the trenches and other works of the attack must be laid out, and the facilities of an easy communication between the parks, dépôts, &c. and the point selected.

65. In considering the strenghth of the defences, those parts are regarded as unassailable by the ordinary measures of an attack which border upon precipices, marshes, a water course that cannot be forded, or are protected by works on inaccessible points, the fire from which sweeps in flank and reverse the ground over which the trenches must be run. Those parts again are considered as offering peculiar difficulties which present a series of works

in good defensive relations which can only be carried in succession; or which are mined; or which have their ditches arranged for a play of water; or which have dry ditches of unusual depth; or finally where the works to be carried are displayed on a right line embracing the same extent of front that the besieger can take up with their trenches. The points which are looked upon as most advantageous to the attack are those in which the general combination of the works form a salient point with respect to the rest of the defences; as a point so situated can receive but little support from the collateral portions, can be envelloped by a line of trench of much greater extent than itself, along which positions can be obtained for enfilading and other batteries, the fire of which will be convergent upon that of the defences.

66. As regards the site on which the trenches and other works must be laid out, the difficulties presented to their construction by bare rock, marsh or hard stony ground may be readily appreciated, as cover can only be had on the two first by bringing the earth from a distance to form the parapets, dikes, &c and on the last from the labor requisite in digging the trenches, and the additional annoyance and injury to the troops from the fragments

of stone scattered in all directions by the shot of the defences. But besides these features there are others less obvious which should be taken advantage of, or be avoided as favorable or otherwise to the construction of the works of attack. A surface for example, which slopes, or falls away towards the defences, if commanded by them, is unfavorable both to the construction of trenches and batteries, as, to gain sufficient cover, both the parapet and trench will have to receive dimensions greater than under ordinary circumstances; and the defilement of approaches will also be less easily effected. A surface which rises towards the defences is very favorable both for gaining cover speedily, and for defiling with advantage the approaches; but is less so as a site for batteries if the slope is rapied. An undulating surface may offer in some points, natural covers, and at others points favorable as sites for batteries; this will depend on the position of the roll of the surface with respect to the fire of the defences. A ridge, for example, leading out from the defences, whilst it would present a cover to the works on one side of it from the fire of the defences on the other, would expose the trenches on the other side of it to a plunging fire from

the same points. A narrow valley similarly placed would be very unfavorable, as both of its sides would be exposed to a plunging fire.

2nd and 3d Periods.

67. **Plan and Journal of the Attack.** The plan of the attack is necessarily based upon the character of the defences of the point of attack, and of the site upon which the approaches and other works of the besiegers must be laid out; and by this term is understood both the means to be used at the successive stages of the operations, and the disposition given to the trenches and other works. The journal of the attack is a record of the daily operations of the besiegers; and is also a method in use among engineers to estimate the duration of a siege from the opening of the trenches to the reduction of the work, on the supposition that the works of the attack can be carried on regularly, without interruption from unforseen contingencies: a method of valuation which, as it is based on the time required to construct a given amount of work, as determined both from data furnished by actual sieges and the results of experiments in schools of practice, may be relied on as an approx-

imation as close as the case admits; and, when applied in a spirit of fairness, may serve as a test of the comparative strength of different combinations, or systems of permanent works.

68. The general disposition of the works of the besiegers is laid down on the map made of the defences and environs with as great accuracy as can be insured by surveys carefully made; and, from the results obtained in this way, the officers charged with this duty are enabled to set out on the ground the necessary points by which those charged with directing the construction of the works are guided.

69. As an illustration of the plan and journal of attack, we shall suppose the Point of Attack selected Pl. XII. Fig. 1. to be an acute bastion with the two adjacent demi-lunes; and that the only collateral works, the fire of which bears on the ground over which the trenches must be run, are two collateral obtuse bastions, the faces of which cannot be enfiladed, owing to their prolongations falling within the salients of the adjacent demi-lunes, and the two collateral demi-lunes, making in all one bastion and two demi-lunes, with their dependent outworks, which must be entered by breach or otherwise; and two bastions and two demi-lunes, with their de-

pendent works, the fire of which must be kept under.

The approaches will be pushed forward in the direction of the capitals of the three first works, and the 1st and 2nd parallels will embrace a sufficient front to include the prolongations of the faces of all the works bearing on the trenches against which enfilading batteries will be requisite.

The 1st parallel will be laid out at 600 yds from the most advanced salients of the covered ways, and parallel nearly to the line which connects these points. The approaches which lead from it to the depôts of the trenches will be run in zig-zags across the capitals, each not over 100 yds in length, and defiled from the most dangerous points within cannon range.

70. 1st Night. The position of the portion of the trenches upon which the besiegers are to break ground having been laid out, and the materials for the work having been placed in order for distribution, so as to avoid all unnecessary delay and confusion, the workmen are assembled at the depots of the trenches before night-fall to receive their implements. The men selected for this duty are troops of the line, and each man usually takes with him his gun slung to his back. The men are

divided into working parties, each of which is under the command of an officer of the line, and they are marched in single file by a flank and posted after night fall where they are to work under the direction of the engineers.

The portion of the trenches opened this night are usually only the approaches that lead from the depôts of the trenches to the 1st Parallel, and that portion of this parallel which embraces the capitals of the point of attack. To guard the workmen from sorties, as many battalions of the line as may be requisite, termed the Guards of the Trenches, are thrown forward about 30 paces in advance of and on the flanks of the men who open the 1st parallel. The flank companies of these battalions, divided into sections, cover the front of the battalions, and are posted about 30 paces from them; and each section posts two sentinels at about the same distance to its front. The sentinels keep a look out, kneeling on one knee; the remainder of the troops lie flat on the ground, to avoid the fire of the defences.

When the working parties are all posted, each lying flat until all are ready to commence the work, the order is given to rise, ground their

arms a few paces to the rear, and break ground.

The guards of the trenches keep their position until near dawn, when they are withdrawn and take post in the parallel, which by this time will be nearly excavated to its full width.

On the succeeding day all that remains to be done to the trenches opened is completed, and every thing is got in readiness for coming night.

2nd Night. The parallel will be extended this night to embrace the prolongations of all those faces to be enfiladed, and some 100 or 150 yds beyond the extreme points so determined. A large square redoubt will be thrown up at each extremity of the parallel, which will be armed with field pieces and an epaulment for cavalry will be thrown up in the rear of each redoubt; the object of these works being to contain troops to act against sorties made on the flanks of the parallel.

The zig-zag approaches are pushed about 150 yds in advance of the parallel. The position of these approaches will be determined by setting off a point on the 1st parallel at 30 yds on each side of the capital, and taking the direction of a line from each of these points to a corresponding one about 15 yds on the side of the capital at the

salient of the covered way. then limiting the length of each zig-zag by these lines the direction of each depending on its defilement. To cover more completely the reverse of each zig-zag. and secure it from positions that might be taken up exterior to the defences to enfilade it; the zig-zag in advance should be prolonged back beyond the limiting lines a distance of 10 or 12 yds to the rear of the one immediately behind.

It may be observed here that by running approaches upon three capitals we not only multiply the facility of communication between the parallels, but divide the attention of the besieged. The direction of the capital is also the most suitable for these trenches on several accounts: 1st they are the shortest lines between the parallels and the salients of the defences, 2nd being within the angle formed by the prolongations of the faces, they are less exposed to the fire of the defences, and are less in the way of the fire of the besiegers than in any other position; 3d in this position they are most easily defiled from the collateral fire.

By confining the zig-zags within the lines drawn from the parallel and converging towards the salients, the front of each approach is

gradually contracted as it nears the salient;
offers less obstruction to the fire of the parallel.

The trenches and other works left in
plete at the end of the 2nd Night are finishe
on the following day; and thus rule is followe
throughout, as the trenches commenced by ni
are generally in a suitable state by dawn to p
cover to the workmen and troops, and are be
carried, and what remains to be done to them
completed in safety by day.

3d Night. The approaches are push
forward 275 yds from the 1st Parallel, and here
2nd Parallel is commenced, a small portion of it only in ea
of the approaches being opened, in which to lodge a few tr
for the protection of the workmen.

This Parallel is of less extent than the
embracing only the prolongations of the faces
the Point of Attack. It is usually connected a
the 1st Parallel by a defiled line of trench at
of its extremities. Its distance from the 1st is
determined from the consideration that the wor
men employed on it must be protected by the f
of the Trenches who are still stationed in the
and who to afford this protection should be nea
where they can come to the aid of the workm

before the garrison can reach them in a sortie.

The rule here observed is also a general one. The trenches under construction never in any case being advanced so far that the guards in their rear cannot come up to their support before they can be reached by a sortie from the defences.

4th Night. The 2nd Parallel is entirely laid out on this night and is completed on the following day. The Guard of the Trenches takes post on the Parallel as fast as a part of it is finished. A reserve equal to about 1/3 of the whole being left in the 1st Parallel.

As the 2nd Parallel is at 325 yards from the salient of the place the workmen are much exposed to the fire of grape shot, it will therefore be necessary to use the flying sap in its construction.

5th & 6th Nights. Thus far the works of the attack have been pushed forward without the aid of artillery, but beyond the 2nd Parallel the fire of the defences becomes so destructive that further progress cannot be made without great sacrifice of life until it is silenced. To effect this enfilading, mortar and counter-batteries are placed about 300yds in front of the Parallel. The number of guns in each battery will depend on the importance of the fire

to be silenced, and according to this rule the fir
ing distribution will be made.

A battery of 8 pieces will be erected a
each face of the Bastion of Attack. A battery o
pieces will be erected against the right face
Demi-Lune of Attack and its covered way,
one of 7 pieces against the left face since th
from the latter bears more directly on the ap
proaches than that of the right face. As the t
collateral bastions are supposed to be so obtuse
their faces cannot be enfiladed, it will be neces
to silence their fire by counter batteries. As th
face alone of the bastion on the right of the
of attack has a direct action on the Approach
counter battery of 5 pieces is erected against
and so placed as to obtain a slant fire into
embrasures With regard to the collateral demi
on the same side, as the right face has but a sl
bearing on the Approaches, a battery of 3 pieces w
prevent this face from being crowned by the be
but as the bearing of the left face is more d
it will be necessary to establish a battery of 5
against it; this last battery is placed in fron
the 1st parallel. Two or three howitzers form
part of each battery to sweep the covered way

and ditches.

The mortar batteries are placed in positions where they will be most effective, which is usually about midway between the capitals of the works to be reached from them. About 4 mortars are placed in each battery, an allowance of 8 mortars being made for each front embraced by the trenches.

The mortar and gun batteries the fire of which is not obstructed by the trenches in front of them, are sunk. The platforms of the others are on the natural surface of the ground.

Besides these batteries, which will be completed on the 5th & 6th Nights, two or three zig-zags are pushed forward in advance of the parallel on the same nights, if the fire of the besieged is not too destructive.

7th Night. As the enfilading batteries will be completed and armed on the 6th Night, on the following morning they will all open their fire at the same moment, and by night the fire of the place will be nearly if not entirely silenced. The Approaches are then pushed forward and Demi-Parallels are established at from 100 to 150 yds in front of the 2nd Parallel. The Demi-Parallels may be from 100 to 200 yds in

length, and have a return of 20 yards at the extremities to cover them on the flank. The length the 2nd Parallel should be so regulated as to obstruct the fire of the nearest batteries. 2 or 3 cases howitzers are placed in batteries established at the extremities of the 2nd Parallel to enfilade the covered ways. But as the 2nd Parallel are in good musket range of the covered ways it will generally be better to arm them with infantry. One of these embrasures being arranged with sand bags to make well sand bags to cover the marksmen when in the act of firing.

5th Night. On this night the approaches are pushed forward by the flying and full sap. opportunity may offer. and a portion of the 3d Parallel is commenced, when the Approaches are within 60 yards of the most advanced salients.

6th Night. The 3d Parallel is completed. It should present a less direct front than the 2nd as to be flanked by it. and will therefore require only the salients of the Point of Attack [illegible] this, and its having to receive the main body of the Guard. (the 2nd Parallel now sometimes only to reserve, whilst the 1st is used only as a depot for materials and to receive the wounded, the 3d pa

lel is made two or three feet wider than the other two.

With the completion of this parallel begins the 3d and last Period of the Attack. At this point, the works of the besiegers are necessarily contracted to a very narrow front, and present but little more development than that of the Head of Attack. They are now upon the immediate ground of the defences, and within range of every means of annoyance. In pushing forward from this position the besiegers are to a great degree deprived of the assistance that they hitherto had from their enfilading and other batteries, as the position of their trenches on the glacis must obstruct this fire; they can no longer use the zig-zag approach, but have to gain ground by the double sap, and soon find themselves, as their works advance towards the re-entrings, the enveloped instead of the enveloping party, and liable at every moment to have their sappers cut off, and their labors stopped by sorties in small parties. It is at this stage then that more than ordinary precautions are requisite, not only to prevent retardation of the works but to avoid unnecessary sacrifice of life; by preparing all possible means for insuring the success of each step and by not advancing one until the last taken is perfectly secure.

from its position on the glacis, will mask the fire of
ricochet batteries against the covered way it will be n
sary to establish new batteries in front of it to dislod
besieged from this outwork. For this purpose stone r
batteries are found very effective. These batteries
placed at about 20 yards in front of the parallel,
are sunk. A battery of 4 or 6 mortars is placed on
side of the salients nearly in the prolonged direct
of the covered ways. These batteries will be ready to
mence their fire on the covered ways on the morn
after they are begun.

After the completion of the 3d Parallel
parations are made for crowning the covered way with
storm, or by gradual approaches. In the former
portions of the Parallel are arranged with steps t
able infantry to sally from it on the covered ways
sappers, with all the necessary materials for crown
the covered way, are collected in the Parallel. A
preconcerted signal a fire will be opened from th
mortar batteries, and all others that are still eff
against the covered way, and the other outworks
it is perceived that the fire has produced its effe
clearing the outworks at a preconcerted signal
will also cease, the troops will sally forth and c

the covered way with the bayonet, and after gaining possession of it, they will shelter themselves as they best can behind the traverses from the fire of the besieged. Whilst they, in this way, maintain possession of the covered way, the sappers, who follow immediately in their rear, will open a trench about 4 or 5 yds from the crest of the glacis around the salient place of arms as far as its two traverses; when this trench will afford a shelter to the troops they retire from the covered way into it. This trench is afterwards connected by other suitable communication with the 3d Parallel.

From the circumstances under which this operation is carried on it is evident that its success must be attended with great loss of life if the besieged, who should be prepared for it, show any conduct; and that every probability is against its success and in favor of a great sacrifice of life if the besieged offer a vigorous resistance, and make a skilful use of the means still at their disposal. With such chances therefore of failure, and the certainly of unusual bloodshed even if successful, there can be no dispute that nothing can justify this kind of attack but some contingency so urgent as to leave no doubt of the success of the siege depending on it.

11th Night. When the covered way is to be

10th Weight. As the 3d Parallel Pl XII Fi
from its position on the glacis, will mask the fire of th
ricochet batteries against the covered way it will be nec
sary to establish new batteries in front of it to dislodge
besieged from this outwork For this purpose stone mo
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will also cease, the troops will sally forth and ca

the covered way with the bayonet, and after gaining possession of it, they will shelter themselves as they best can behind the traverses from the fire of the besieged. Whilst they, in this way, maintain possession of the covered way, the sappers, who follow immediately in their rear, will open a trench about 4 or 5 yds from the crest of the glacis around the salient place of arms as far as its two traverses; when this trench will afford a shelter to the troops they retire from the covered way into it. This trench is afterwards connected by other suitable communication with the 3d Parallel.

From the circumstances under which this operation is carried on it is evident that its success must be attended with great loss of life if the besieged, who should be prepared for it, show any conduct; and that every probability is against its success and in favor of a great sacrifice of life if the besieged offer a vigorous resistance, and make a skilful use of the means still at their disposal. With such chances therefore of failure, and the certainly of unusual bloodshed even if successful, there can be no dispute that nothing can justify this kind of attack but some contingency so urgent as to leave no doubt of the success of the siege depending on it.

11th Night. When the covered way is to be

crowned by regular approaches. a constant fire is ke
up from the stone more batteries so as to render it
tenable for more than a very few men. A trench,
med the Circular Place of Arms is now formed, by
ing from two points of the parallel at 30 yards o
side of the capital, and pushing two branches of
sap to unite at about 15 yds from the parallel
the capital. From this point a double sap is pus
along the capital to within 30 yds of the salients o
the demi lune covered ways. As the bastion cove
way is very retired nothing more is done than
form the circular place of arms before it.

12th Night. The trench cavaliers befo
the demi lune salients are commenced, and the
is pushed forward a few yards on the bastion c
ed way.

13th Night. The trench cavaliers, whic
require from 36 to 48 hours for their completion, u
be finished on this night, and an Approach push
from the stone mortar batteries towards the re entr
place of arms.

14th Night. The besieged being now dri
from the covered ways by the fire of the trench cav
liers, a double sap is pushed towards the salient
the demi lune covered way from the two extremi

of the circular trench connecting the trench cavaliers. These two saps unite at 4 or 5 yds from the crest of the glacis.

The Approaches towards the re entering place of arms are advanced farther on.

15th Night. The demi lune covered way is crowned as far as the 2nd traverse. The Approaches on the re entering place of arms and the salient of the bastion covered way are advanced.

A 4th Parallel is begun on this night; commencing opposite the 1st traverses of the demi lune covered ways, and uniting the Approachspushed towards the re entering places of arms.

16th Night. The breach and counter batteries around the salient place of arms of the demi lune are completed and armed.

From 4 to 5 guns will be placed on each branch of the glacis of the salient place of arms, in the prolongations of the demi lune ditch, to counter batter the portions of the bastion faces which bear upon this ditch and the covered way, and prevent this fire from retarding the lodgments about to be made on the terre-plein of the salient place of arms, and the passage of ditch. About 4 guns are placed in a battery between the 1st and 2nd traverses, to open

a breach in the left face of the demi-lune. This bre
should be from 20 to 30 yds in width, and not ex
farther towards the salient than the position of th
coupé, so as to expose as great an extent of the in
of the demi-lune as practicable.

The guns in these batteries will requ
cover in flank from the faces of the bastions
their cavaliers; and in rear from the most adv
salients of the works still occupied by the besieg

The descent into the demi lune cover
way, commenced on the 15th Night behind th
traverse, is finished; and the 4th Parallel is
pleted. The width of the 4th Parallel is the
as an ordinary Approach owing to the difficul
defiling it.

These batteries will be completed and
in 24 hours after the crowning is commenced
breach will be practicable in 12 or 15 hours aft
the fire is opened.

17th Night. The Approaches from t
Parallel are pushed forward on the salients of
bastion covered way, and the re entering plac
arms. The crowning of the demi lune covered
is gradually advanced and a lodgement is
on the terre plein of the demi lune salient pl

of arms from which the demi lune ditch can be swept by musketry.

The descent into the demi lune ditch is commenced on this night behind the traverse of the salient place of arms.

In advancing the sap on the different salients of the covered way, from the 4th Parallel, care should be taken not to push forward one faster than the others, so as not to offer a temptation to the besieged to sally out on the head of the most advanced, to cut off the sappers Moreover the different brigades of sappers should be protected by a few picked men stationed in short trenches that flank the direction of the double sap as it is pushed forward on the salients.

If owing to the great width of the covered way, or to the small breadth of the demi-lune ditch, or to the steepness of the glacis by which the batteries placed along its crest would be very much exposed to a reverse fire from the collateral works, it should become necessary to place the breach and counter batteries on the terre plein of the covered way, they cannot be completed and armed before the 17th or 18th night. Although the batteries in this position would be well covered from reverse fire by the crest

of the glacis, and from a flank fire by the traverses of the covered way, still they would require much more labor to establish them, and would be more exposed to the annoyance of grenades thrown from the demi lune.

After the descent into the demi lune ditch is commenced it is steadily carried forward until it arrives at the point opposite the breach where the opening into the ditch is to be made through the counterscarp wall. This opening should be pierced at night, and the precaution should be taken to run a small gallery along the back of the wall, on each side of the opening, so as to place a few men to fire through loopholes made in the wall, for the purpose of defending the opening and the sap pushed across the ditch to the breach.

18th 19th and 20th Nights. The Approaches from the 4th Parallel and the crowning of the covered way are pushed forward and completed on these nights.

It will seldom be practicable to establish a trench cavalier against the bastion salient place of arms owing to the reverse fire from the collateral demi lunes. In such a case, if the besieged still occupy this work in force, so as to retard the pro-

gress of the sap, an attempt must be made to dislodge them by an open attack of a small party of picked troops, or else stone mortar batteries may be placed in the position that would be occupied by the trench cavaliers by means of which the besieged may be driven from this part of the covered way.

So soon as the bastioned covered way is crowned two descents are commenced into the main ditch from the trench at the salient of the covered way.

In very acute bastions the breach and counter batteries along the bastion covered way might be completed on the 21st Night. But generally, before this can be done the demi lune must be carried, as its fire would take these batteries so in reverse as to render their construction impracticable.

25th Night. The descent into the demi-lune ditch and passage of the ditch may be effected by this night at farthest.

Every precaution should be taken to prevent the besieged from interrupting this passage. The passage itself should be 4 or 5 yds wide at bottom, to afford a convenient place of arms for the troops

and it should be arranged with a banquette to sweep the ditch by a close musketry fire.

Besides making loop holes in the count scarp wall to flank the passage, it will also be well to push forward one or two zig-zags in the ditch itself and place a small party of picked men in them to repel the sorties of the besieged.

The breach is gained possession of either by storm or by gradual approaches. The former will be resorted to when the besieged manifest a determination to keep possession of the demilune in force to the last extremity. A few companies of picked men will be chosen for this service. All the materials will be collected at hand for crowning the breach, and when every thing is in a state of readiness a warm fire will be opened on the breach and on all the works that in any way bear upon it. At a preconcerted signal the fire will cease, and the assaulting column, rushing through the breach, will drive the besieged from the demi lune, and then, sheltering themselves as they best can from the fire of the other works, they will maintain possession of the breach until the sappers, who follow in their rear, can effect a lodgment on its top.

To make the lodgment by gradual approaches the sappers will push forward a sap from the foot of the breach, over the ruins, giving it such a direction as to gain a shelter under the end of the wall that remains, on the side of the breach which is exposed to the fire of the besieged. A few picked men will cautiously mount to the summit of the breach, occupying such sheltered points as may be found at hand, for the purpose of covering the sappers whilst at work. These men will be sustained by a detachment posted along the passage of the ditch.

26th Night. The lodgment on the breach of the demi lune being effected on this night, the breach and counter-batteries along the bastion covered way, and against the redoubt of the re entering place of arms, can be completed and armed.

A breach battery of 4 guns will be placed along each crest of the bastion covered way, as far from the salient as room can be had, for the purpose of opening as wide a breach as practicable at the bastion salient. A counter-battery likewise of 4 guns will be placed along the same crest, and in the best best position to fire in the prolongation of the main ditch and silence the fire of the enceinte flanks opposite to them. A breach battery of 3 guns will also

be placed against each of the redoubts of the re-entering place of arms, to open them on their faces that lie adjacent to the demi-lunes.

These batteries are covered in flank and rear in the same manner as those against the demi lune

To prevent the besieged from attempting to dislodge the besiegers from the demi lune, it will be well to construct a trench across its terre plein, from which the ditch of the demi lune redoubt can be swept by a fire of musketry. This trench may be made on the 27th Night.

So soon as the demi lune breach is secured a descent is commenced from the lodgment on it to the ditch of its redoubt.

This descent and the passage of the ditch of the redoubt will take until the 32nd Night.

In the mean time zig-zags will be pushed forward in the demi lune ditch towards the glacis of the single capponniere: and a double one will be formed in the gorge of the demi lune itself, to overlook the ditches and to approach the cut in the demi lune face.

A descent may also be made on or before the 32d Night into the re entering place of arms, and

a lodgment be effected on its terre plein

On the 32nd Night miners are set to work at the scarp wall of the demi lune redoubt, and at the scarp and counterscarp walls of the cut. The mines may be completed and fired and the lodgment be effected on the breaches by the 34th Night. At which time the breach in the redoubt of the re entering place of arms is also carried.

When a breach can be effected in the bastion face through the opening of the demi lune ditch, the zig-zags in this ditch might be pushed forward nearly to the extremity of the ditch, and the passage of the main ditch opposite the breach in the salient be effected by the 33d Night; so that the breaches in the body of the place, and those in the redoubts and the cut might all be carried on the 34th. But when the breach cannot be effected in the face of the bastion through the demi lune ditch, and it is deemed advisable to effect one at this point, then it will be necessary to carry the outworks first, and afterwards to push forward the sap to crown the glacis of the single capponniere in the demi lune ditch, where a breach battery of two guns may be established; at the same time a lodgment is made behind the bastion covered face and a breach battery

of 4 guns is established there. These labors will require for their completion until the 37th Night. In the mean time lodgments are effected on the upper and lower terre pleins of the demi lune redoubt, and on its parapet, to overlook the main ditch, the double caponniers, and the tenailles.

The passages across the main ditch are also completed, the descent to the one nearest the shoulder angle being commenced from within the postern of the redoubt of the re entering place of arms.

38th Night. The lodgment on the breaches in the bastion will be effected on this night, and a descent be commenced from the top of the breach to the ditch of the cavalier.

39th & 40th Nights. A lodgment will be effected on the bastion terre plein, and a breach battery of 4 guns be established against each face of the cavalier.

The breach in the cavalier and the descent into the ditch will be completed so that the final assault may be made on the 41st Night.

Defence

71. The object of this like the preceding section is to give a succinct detail of the operations of the Garrison during the successive stages of the attack supposing the works which they occupy provided with every thing requisite for conducting the defence vigorously.

During the investment the garrison will resort to every means for cutting off parties of the investing corps which approach the work incautiously, and will particularly endeavour to prevent all attempts at reconnoitring. About one third of the garrison will be kept on this duty, taking post around the work during the investment and as long after as they can maintain their position without too great danger.

As the defences at this period have no other danger to apprehend than a surprise, and nothing to annoy by a fire but reconnoitring parties, the artillery will be so posted as to be of most service in these cases. Two field guns, loaded with grape, should be placed in embrasure on each flank, and one or two more on the bastion faces to sweep the ditches of the demi lunes with grape, to frustrate any attempt at a surprise; and two or three

heavy guns with long ranges should be placed en
batte in each of the salients of the bastions and
demi lunes to keep reconnoitring parties at
distance.

Whatever precautions may have been
by the besieged to conceal the intended relative to
point of attack, and the time of opening the fir
es (by keeping a strict watch on all the movemen
of the former) are usually enabled to ascertain
with tolerable certainty, and to prepare themse
accordingly. So soon as these points are known
garrison shall keeping on the alert to frustrate
attempts of surprise, and without hesitancy
may unmask the artillery already in position
direct all the disposable pieces in reserve to th
next eligible on the points of attack and the
lateral works to do the most damage to the ass
and the guard of the trenches before they rea
at under cover in the 1st parallel. Some active
officers should be employed to reconnoitre
and ascertain the position of the batteries and
troops, and so soon as they are discovered a hea
fire of grape &c will be directed on them from
the guns that can be brought to bear on their
position at the same time a few howitzers or

keep up a ricochet fire in the direction of the capitals to annoy the workmen at the approaches.

After an interval of two or three hours the parapet of the parallel will be proof against grape shot, and then a fire of balls and hollow projectiles will be commenced and directed both along the capitals and to take the guards and parallels obliquely.

Unless the garrison is very strong, or the besiegers show a want of proper precaution in covering their laborers by a strong guard, sorties cannot be made at this period of the attack with much prospect of success, owing to the distance of the parallel from the defences. The most that ought to be attempted will be to make some charges of cavalry to cause the laborers to stand to their arms and thus retard for a short time their operations.

72. When, from the indications without, there is no longer any doubt respecting the real point of attack selected all the disposable artillery will be brought forward and placed in barbette in the best positions on this point and the collateral works, for sweeping the ground over which the trenches must be pushed. In the mean time embrasures, platforms, and traverses are prepared on the most

suitable positions to place the artillery under sh
so soon as the enfilading batteries are completed

The following armament may be tak
as a mean for this period of the defence. Eleven
pieces in the bastion of attack, one of which is an
inch howitzer firing in the direction of the capi
the others may be 18 or 24 Pdrs. five being place
on each face.

Seven or nine pieces of like caliber - or
similarly disposed - may be placed on the cour
of the bastion

Eleven pieces will be placed in each en
lune of the attack, one 8 inch & one inch howitzer
to fire along the capitals. the others 12 or 18 Pdrs.
six of which are placed on the face that bears on
the ground opposite the bastion of attack. the th
three on the other face.

Five pieces of heavy calibre on the fac
of the two collateral bastions which bear most
directly on the trenches. and their flanks which
on the bastion of attack should each receive four
pieces near the angle of the curtain

In the collateral demi lunes six piece
are placed on the faces alone that bear on the
trenches.

Besides the preceding, sixteen 8 inch howitzers should be placed in the covered ways of the point of attack and of the two colateral fronts; two being in each place of arms to fire in ricochet along the capitals. About twenty mortars should be distributed along the curtains, and in the demi-lune redoubts.

The pieces on the faces which are enfiladed should be covered by gabionade traverses; placing a traverse between every two pieces. The barbettes in the salients will be partly cut down, and the parapet be raised, to form merlons and embrasures for the guns at these points.

An uninterrupted fire should be kept up on the parts of the trenches in progress, particularly when the besiegers commence throwing up the enfilading batteries. The fire should be concentrated on a few of the principal batteries rather than scattered over all, because by delaying the progress of these the others if the besieged act prudently will not open their fire until all are ready.

If the approaches are not well defiled, or are directed too near the salients, works, termed counter approaches, may be made from the covered way to enfilade them. These works are usually small redan batteries, placed near the foot of the glacis to receive the artillery in reserve not required for the immediate defence of the work. They are connected with the covered way by

an ordinary trench These batteries are kept armed only during the day, and are protected by small detachments of about 50 men to secure them from surprise.

During this period the engineer officers and workmen are employed in organizing the point of attack for a vigorous defence. The covered ways are palisaded with care. Tambours, or block houses, are established in the salient place of arms, and also in the re entering places of arms if there are no permanent redoubts. Similar arrangements are made in the demi-lunes which have no redoubts; and interior retrenchments either of a temporary or permanent character are made in the bastion of attack. Easy communications are established between all the works.

With regard to the portion of the garrison on daily duty the greatest number will be posted in the defences more immediately threatened by the besiegers. About 40 men may be posted in each salient place of arms of the point of attack and 20 in the collateral salients; about 80 in each re-entering place of arms of the same point, and 40 in each of the collateral ones. Besides these there should be a detachment of about 10 men in each demi lune of the point of attack. The number and disposition of the daily guard will of course vary with circumstances. The main post

to be attended to is that no part of the work of any importance shall be left without a sufficient force to hold the besiegers in check in case of surprise, until support can be obtained from the main body, which last should be so distributed as to be able to carry succour promptly to any part threatened, or attacked.

So long as the besiegers are beyond musket range the guards in the covered way have only to keep on the alert, and to send forward in the day time a few picked men who take advantage of any shelter to approach the trenches and fire on the workmen, or guards who are exposed; and at night to keep out patroles to scour the ground arround the work; to annoy the workmen when an opportunity offers; and to prevent the approach of reconnoitring parties. So soon as the trenches are pushed forward within musket range, an uninterrmitted warm fire of musketry is kept up on the workmen and guards that are exposed, some 8 or 10 good marksmen being placed in each salient for this service.

Sorties may be made with more chances of success when the besiegers commence the 2nd parallel, as the guards of the trenches in the 1st parallel are not so near at hand to protect the workmen as during the construction of the trenches up to this point.

The detachment for the sortie, consisting of

3 or 400 infantry, will sally from the covered ways to attack the 2nd parallel on one or both flanks, and, if circumstances favor in front. When the workmen are put to flight, instead of pursueing them into the 1st parallel, the detachment will form in battle order to cover a party of some hundreds of workmen, who follow in rear of the detachment whilst they are filling up the trenches, destroying the implements, and setting fire to the gabions. The working party will be covered on each flank by a detachment of infantry and all the disposable cavalry of the place. When the guards of the trenches appear in force to repulse the sortie the troops will retreat slowly, without compromising their safety, and will endeavour to draw the besiegers in the pursuit within short range of case shot, a fire of which will be opened on them so soon as the retreating troops are out of danger from it. This operation, if successful, may be repeated several nights in succession; the best moment is just before dawn, when the guards of the trenches are fatigued and sleepy with watching. Although the chances of success are greater at this stage than at the opening of the trenches, still if the besiegers take proper precautions, the sortie will in all probability prove more prejudicial than advantageous to the besieged.

Before the besiegers open the fire of the en-

filading batteries the fire of the defences will be concentrated, as has been said, on the principal of these, and will be kept up against them until a marked effect is observed in the fire of the enfilading batteries. Only one gun will then be left between each traverse on the faces of the defences, the other are withdrawn and kept in reserve. The guns and howitzers kept in battery will fire steadily on the heads of the approaches as they are gradually advanced.

73. After the 3d parallel is constructed the howitzers may be replaced with advantage by stone, and Cochorn mortars, firing from the covered ways and the redoubts of the re-entering places of arms. Guns will be placed in embrasures to fire in the direction of the ditches of the demi lunes of attack against the crowning of their covered way.

At this stage the musketry fire of the besiegers becomes very destructive to the artillerists whilst serving the guns. Strong oak musket proof blinds should be arranged to mask the mouths of the embrasures when the guns are not in battery. Blinds or covers of timber and earth under which guns can be secured from projectiles that would reach them at top or in flank will now be very serviceable. A few guns covered in this way, and placed in the

salients of the collateral works, to obtain a reverse on the trenches constructed on the glacis, will pro a serious annoyance to the sappers and will grea retard their progress.

The troops in the covered ways will ke up a warm fire of musketry against the heads o the sap, and on every exposed point. The men fix occupying points where they will be best sheltered can best see the leading sappers. A few marksmen will also occupy the parapets of the demi lunes a the redoubts to keep up a fire from them, but onl during the day, as at night this fire might injur the men in the covered ways.

The greater part of the guards of the covered should now be withdrawn at night and be posted in demi lunes and the redoubts, so as to expose but few troo if an attack by storm is made.

Although sorties in large bodies will seldom prove successful after the 2nd parallel is finished, the made by small detachments of 10, 20 or 30 men a the head of a sap, or other work, when the besiegers a advancing beyond the 3d parallel will seldom fail if c ducted with proper precautions.

This method of annoyance will be particularly serv able during all the subsequent stages of the defence

the besiegers cannot now have at hand a very large force.

The defence of the covered ways will be regulated by the method pursued in the attack. When the latter is made by gradual approaches, the troops with the exception of a few men who can find a shelter behind the short crotchets, will be withdrawn from the salient place of arms so long as these are annoyed by the fire of the stone mortars, when this fire ceases, which takes place when the sap is pushed forward from the 3d parallel, the troops again enter the salient places of arms, and renew their fire on the heads of the sap, directing it particularly against the sappers working at the trench cavaliers. When the trench cavaliers are completed and armed, the troops again retire from the salient places of arms, and occupy the traverses and short crotchets where they maintain their fire, and throw hand grenades on the sap when it comes within their range. Stone and Cochorn mortars are also placed behind the traverses to annoy the sap &c.

If the besiegers are observed to be making preparations to attack by storm no more troops than will be required to line the parapet of the covered way should be posted in the more salient parts, and they should maintain their position no longer than is necessary to give the storming party one volley as they débouche

from the 3d parallel; retreating immediately after to
main ditch, or to other designated points. A reserve
about 100 men is posted in each re entering place of a
to cover the retreat of those from the salients. All the ot
outworks are lined with troops, and such pieces as ca
still be brought to bear on the glacis, loaded with c
shot, open at the same time with the infantry a de
fire on the storming party, which is kept up until th
assailants are either driven from the covered ways,
take shelter in the trenches constructed by the sap
along the crest of the glacis. A vigorous sortie both on
the front, the flanks, and the rear of the stormi
party made from the collateral covered ways will
such cases be a judicious operation.

As the moment for crowning the covere
way approaches the efforts of the besieged will be re
doubled to retard the works of attack. Independe
of the measures already laid down the besieged wi
arm with artillery the flanks which bear on the
point of attack, and will construct oblique emb
in the curtains to sweep the positions along the b
covered ways where the besiegers are making the ba
and counter batteries. The guards of the covered wa
will retire towards the re entering as the crownin
of the covered way advances, disputing the grou

foot by foot, and holding possession of each point until the besiegers are nearly in a situation to envelope it with their works. The stone and Cochorn mortars will be removed to the re entering places of arms, or into some of the communications in the rear from which a fire can be kept up on the trenches. In fine every possible means will be resorted to by which the sappers constructing the breach batteries and the descents can be cut off and their labors be retarded.

74. When the besiegers have established themselves so strongly on the glacis and the covered way that sorties in small parties cannot be made without too great risk, a warm fire of musketry will still be kept up on the trenches from all the outworks, and the besieged will wait until the descent of the ditch débouches at the counterscarp before renewing the same game of sorties in small parties. A vigilant look out will be kept to ascertain this moment, and so soon as the sappers show themselves every effort will be made to cut them off, and destroy their work, by opening a fire both of artillery and musketry on the débouche, by sorties in small bodies, and by throwing loaded shells, grenades &c, into the ditch.

On wet ditches filled with stagnant water the besieged will resort frequently to night attacks ...

boats on the dike or passage; and in the case where a can be suddenly let into or be drawn from the dike of water will be used to sweep away the besiegers work

In defending the breach of the demi lune besieged will resort not only to the fire of the redoubt will erect barricades on the right and left of the br across the demi lune here also, from which a war fire of musketry will be poured in on the besieger whilst they attempt to gain possession of the brea either by gradual approaches or by storm. Small or bomb fougasses, should be prepared at the summ the breach to be exploded as soon as the besiegers p possession of it. The top of the breach will be stre with every possible obstacle that can retard the p gress of the storming party, and grenades thunde barrels, &c. will be rolled over on the troops whilst m ing the breach

The measures for the defence of the main ditch and of the breach in the bastion face diffe nothing from those resorted to for the demi lune The besieged will make every effort to keep possessio of the ditch to the last moment; by occupying the c capponnieres and the tenailles, from each of which a steady fire will be kept down the besiegers whi effecting the passage. Sorties of small bodies of mi

troops will be frequently made under the protection of
[illegible] by the fire of the tenaille &c. The posterns at
this period require to be guarded with peculiar vigilance
to prevent the besiegers carrying them by surprise and
thus effecting an entrance into the interior of the work.

An assault of the breach in the bastion cannot
be opposed by the bayonet without compromising the lives
of the garrison unless there exists a good interior retrench-
ment to cover the retreat from the breach; even in this
case to oppose the storming party with the bayonet
will be an operation of great delicacy, for the besieged
if driven back may not be able to effect their retreat with-
out being so mixed up with the assailants as to render
it impossible to prevent the latter entering with them
into the retrenchments.

Finally when the breach is effected in the
interior retrenchment the besieged may offer to capitu-
late, unless they are still able to protract the resistance
a day or two, by organizing temporary defences, and
by placing the houses in the rear of the retrenchments
in a defensive state, in which cases this breach should
be disputed with the same obstinacy as those of the
other works.

Relative Strength of the Garrison and Besieging Force

75 ... a permanent work should force an enemy to resort to an attack by regular approaches. its garri should be at least of sufficient strength to prevent its be carried by a coup de main, or open assault The larg garrison will depend upon the means provided with the work for lodging troops, and securing properly munitions of war requisite for the number that can recommended during the presumed duration of the defence. Between these two limits the best military authorities estimate as a medium garrison, capable making a good defence, 600 men per front, or bastio this force being composed of the different arms of servi in the proper proportions for the duties required of them. When the defences comprise besides the encein some of the principal outworks, and it is intended t occupy them strongly, with a view to an active vigorous defence, an allowance from 900 to 1000 me should be made per bastion.

With respect to the quantity of artillery necessary for the armament of a permanent work. there is considerable discrepancy of opinion amo military writers A resolute garrison might resis

a work of tolerable strength from a coup de main without the aid of cannon; and an idea of the largest amount of artillery might be arrived at, by supposing each front to be armed with as many pieces as it can carry, with the addition of a suitable number of pieces in reserve to provide for casualties. But these are inadmissible extremes, and a medium estimate is to allow 3 heavy guns and one heavy mortar per front or bastion, with 60 heavy guns, 20 heavy mortars and 10 stone or light mortars for the armament of the Point of Attack.

In estimating the amount of ammunition an allowance of 1000 rounds is made for each gun. 800 rounds for each mortar. 100 musket cartridges per day for each soldier on guard; and 300 lbs of powder for each mine

76 The strength of the besieging force is based upon that of the garrison. The usual estimate is to allow for the daily duty of the trenches at least as many troops as the garrison, including in this number the men employed in making the trenches. As the service of the besiegers is very onerous, the tour of duty in the trenches should not be more frequent than once in five or six days. Admitting this estimate the besieging force comprising all arms should be at

least five times as strong as the garrison.

In estimating the quantity of siege ar
as many guns and mortars are allowed for the
filading, counter and mortar batteries as the p
armament of the Point of Attack; with an ada
of 40 or 50 heavy guns for the breach batteries.

The medium allowance of ammunition
the artillery is 1000 rounds for each gun and 800
each heavy mortar.

77. It is hardly necessary to observe that t
above estimates are of a very general character
are introduced here merely to give some idea o
relative proportions in questions. Before undert
the siege of a work, no pains should be spare
gain all the information possible respecting t
state of its defences. and the probable difficul
to be encountered in its attack, and the estima
based on these data should be made on the su
position of the work being provided with all
means of a vigorous defence.

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